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OF
THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

DEVOTED TO THE ADVANCEMENT OF ASTRONOMY AND ALLIED SCIENCES

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The Henry Draper Memorial	*Annie J. Cannon*	203
Location of Epicentres for 1914	*Otto Klotz*	216
Two Spectroscopic Binary Orbits	*Reynold K. Young*	224
Schehallien	*Otto Klotz*	227
Summer Constellations	*J. R. Collins*	235
A New Comet		238
Meetings of the Society		
At Toronto	*W. E. W. J.*	239
At Ottawa	*R. E. DeL.*	242
Review of Publications	*Reynold K. Young*	248
Notes from the Meteorological Service		
Report of the Weather in Canada, April	*R. F. S.*	254
Magnetic Observations	*R. F. S.*	256
Earthquake Records at Toronto and Victoria, B.C.	*J. Y.*	258
Astronomical Notes		
Wolf-Rayet Stars	*J. R. C.*	259
Notes and Queries		262
Black Lightning		264
The Oblateness of Uranus		265
United States Coast and Geodetic Survey		267
Audibility of the Aurora		268
Books Added to the R.A.S.C. Library	*C. A. C.*	269

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PLATE X.

Henry Draper M.D. LL.D.

Born, March 7, 1837 ; died, November 20, 1882.

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VOL. IX. MAY-JUNE, 1915. No. 5

THE HENRY DRAPER MEMORIAL

BY ANNIE J. CANNON

THIS memorial was established in 1886, at the Harvard College Observatory by Anna Palmer Draper, the widow of the distinguished investigator and astronomer, Dr. Henry Draper, who was Professor of Physiology and Chemistry at the University of the City of New York. In his undergraduate days, Dr. Draper became interested in photography, which was then in its infancy. A visit to Birr Castle, Parsonstown, in 1857, to see the famous six-foot reflector of the Earl of Rosse, is said to have increased his interest in astronomy, so that upon his return to America he constructed two reflecting telescopes for his private observatory at Hastings-on-Hudson. After the marriage of Dr. Draper to Anna Palmer in 1867, they resided in the summer at Dobbs Ferry, two miles distant from the Hastings Observatory. It was their custom to drive to the observatory in the evening, and so great was Mrs. Draper's interest that he never went without her. She assisted him by recording, calling out the time, and coating the glass plates. Dr. Draper made numerous photographs of the moon, of the Nebula of Orion, and was the first to photograph the absorption lines in the spectrum of a star. The spectrum of Vega,

taken by him in August, 1872, showed four dark hydrogen lines. He also obtained the spectra of other bright stars, and of the Great Nebula of Orion. Dr. and Mrs. Draper resided in New York City in the winter, where their spacious home was the scene of many brilliant entertainments and where scientific men were accustomed to gather and enjoy the delightful hospitality. In November, 1882, they gave a dinner to the members of the National Academy of Sciences, gathered in New York. At this brilliant dinner, when, as a great novelty, the Edison incandescent bulbs were arranged by Dr. Draper to light the table, and when so much mirth and geniality prevailed, the guests could not have had a suspicion that they would never see Dr. Draper again. He moved about talking with one and another, among them being Professor Edward C. Pickering, who expressed his great interest in the photographs of stellar spectra taken at Hastings, even offering to measure them if they might be sent to Cambridge. Immediately after dinner, Dr. Draper was seized with a severe chill, the fore-runner of pneumonia which caused his death in a few days. The portrait of Dr. Draper is shown in Plate X. Mrs. Draper, wishing to establish a memorial to her husband, at first thought of erecting an observatory in New York City. This proved impracticable, however, and her attention was called to the experiments then being made in the photography of stellar spectra by Professor Pickering, the Director of the Harvard Observatory.

It will be remembered that the first photograph ever taken of a star was made at the Harvard Observatory under the direction of Professor W. C. Bond on July 17, 1850. In 1882, Professor E. C. Pickering's attention was called to the possibilities of celestial photography by Professor W. H. Pickering, and a small grant from the Rumford Fund of the American Academy enabled him to make some preliminary experiments. Two years later, by means of a larger grant from the Bache Fund of the National Academy, he procured a Voigtländer lens, 8 inches in aperture and with a focal length of about 45 inches. This

telescope, as shown in Plate XIV. was mounted in such away that polar stars are easily obtained, and no reversal is required when a star crosses the meridan. Professor Pickering commenced his photographic investigations of stellar spectra, by means of a 13° prism placed before the object glass of this telescope. He had already made visual observations with a spectroscope attached to the 15-inch Equatorial and had discovered eighteen gaseous nebulæ and three stars of Class *O*, often called the Wolf-Rayet type. The objective prism had been used previously by Secchi in his visual observations of the spectra of about 400 stars, and was at this time first applied to the photography of stellar spectra. It has the advantages that there is only a very small loss of light, and that spectra over the entire field are obtained. Any desired width can be given to the spectra by varying the rate of the clock. The original plan to obtain the spectra of all the brighter stars and of the fainter ones in certain regions proved too large for the Bache appropriation, but just at this critical time Mrs. Draper became interested and provided means for continuing the investigation as a memorial to her husband. With his characteristic breadth of vision, Professor Pickering laid out this great work, announcing in 1887, in the First Annual Report of the Henry Draper Memorial, that Mrs. Draper had already enlarged the scope of the work, "so that the final results shall form a complete discussion of the constitution and condition of the stars," including a catalogue of the spectra of all stars north of − 24° of the sixth magnitude and brighter, with a detailed study of the brighter stars.

As soon as the photographs were obtained, the work of classifying the spectra was undertaken, and was soon placed under the charge of Mrs. Fleming. At once the greatest difficulty was encountered. How were the various kinds of stellar spectra shown on these photographs to be designated? The divisions into five types made by Secchi proved altogether inadequate to represent the numerous differences seen on the photographs. A new system had to be adopted which would permit the reader to understand the various aspects of the

spectra as shown by the photographs. Therefore, the letters of the alphabet from *A* to *Q* were assigned to stellar spectra. This classification is purely empirical, being based wholly on the external appearances, without any idea of expressing differences of temperature or stages of evolution. Any system of designation which could assemble all similar spectra under one name was deemed to be sufficient, for, it was stated that whenever a theory could be found to account for all the observed facts, any other name could be substituted and any other order assigned to the classes. The futility of attempting more at this early epoch is shown by the passing of Vogel's classification, in which the aim was made to explain the phase of development of each star. In the Draper classification, the letter *A* was assigned to spectra of the first type, showing the broad hydrogen lines, as in Sirius, the line *K* of calcium also generally being present. When other lines were seen, such as those at wave-lengths 4026 and 4471, the spectra were called *B*. The letters *C* and *D* were used to represent spectra of the first type, having certain peculiarities, such as double lines or bright bands, which were even then suspected to be instrumental rather than real. The letters *E* to *L* were assigned to spectra assumed to be of the second type, with the remark that Class *F* might be considered to be intermediate between the first and second types. The letters *M*, *N*, *O* and *P* were given, respectively, to spectra of the third type, the fourth type, the fifth type, consisting mainly of bright lines, and the gaseous nebulæ. *Q* was left for spectra so peculiar as not to be included under any of the former letters. The first classification of a large number of photographic stellar spectra was made according to this system by Mrs. Fleming and was published in Volume XXVII. of the Harvard *Annals*. It was called the Draper Catalogue and contained 10,351 stars.

Realizing the importance of extending the investigations over the entire sky, in 1889 Professor Pickering sent an expedition to South America, at first in charge of Professor S. I. Bailey, and later of Professor W. H. Pickering. The 8-inch telescope was

taken and, after trials of several places, was finally set up in Arequipa, Peru, where a permanent station was established. Plate XII gives a view of this station. The Observatory and a comfortable residence for the staff were erected at an elevation of 8,000 feet, at the foot of an extinct volcano, El Misti, which is 19,200 feet high. Besides the 8-inch Bache Telescope, the 13-inch Boyden and 24-inch Bruce Telescopes were mounted later at Arequipa. To fill the place of the Bache Telescope in Cambridge, Mrs. Draper furnished a second, and nearly similar, instrument.

All the photographs are stored in the rectangular brick building, seen in Plate XI, which shows the main station of the Observatory, at Cambridge. One of the stack rooms for storing plates is shown in Plate XIII. Each compartment contains 100 original glass negatives, 8 × 10 inches in size. The collection resembles a library of books, of which each negative is the only existing copy, and being glass, is very fragile.

While the general survey of the whole sky was made with the 8-inch telescopes, excellent spectra of the brighter stars were obtained with Dr. Draper's 11-inch photographic lens, having a focal length of 153 inches, which had been remounted in Cambridge. The brighter stars could thus be photographed with a dispersion of 8.00 cm., from $H\beta$ to $H\epsilon$, by means of four prisms nearly a foot square, placed before the object glass. Among the earliest results, it was stated in 1887 that the H line in α Cygni was found to consist of two components, and the lines $H\gamma$ and $H\delta$ were bright in o Ceti. Also that U Orionis which was at first supposed to be a Nova, had a spectrum similar to that of o Ceti, thus furnishing additional evidence that it is a variable of the same class. In 1888, photographs were taken of the spectrum of β Persei at the star's maximum and minimum light to show possible changes, but gave only negative results. These early data are interesting as marking the beginning of the extensive work of the Memorial on the spectra of the variable stars.

The detailed study of the spectra of the bright northern stars was assigned to Miss A. C. Maury, a niece of Dr. Draper.

The photographs used by Miss Maury are excellent ones, taken with the 11-inch telescope, and of large dispersion, which enabled her to detect small peculiarities and make detailed study of wave-lengths and intensities of lines. She formed 22 groups of spectra, using Roman numerals instead of letters to designate them, and calling attention to differences in the width of the lines by assigning the letters *a*, *b*, *c*, respectively, to spectra with medium, wide and narrow lines. Miss Maury's results were published in Volume XXVIII., Part I. of the *Annals* and formed a catalogue of 681 stars. One of Miss Maury's important discoveries was that the spectrum of β Lyræ changes in a remarkable manner, which, in her opinion can be partially explained by the presence of a third body.

The revelations of these early photographs of stellar spectra were truly remarkable. It was almost as if the distant stars had really acquired speech, and were able to tell of their constitution and physical condition. Spectra of such stars as Arcturus were obtained on a scale so as to show 500 solar lines between the sodium line *D* and the calcium line *K*. These lines were compared with lines in the sun by means of Rowland's map of the solar lines. No one could do this patiently, line for line, noting in many cases the perfect agreement, and not be convinced that the distant star is a glowing body on the same order as our own luminary.

In 1888, Professor Pickering made the unique discovery that the lines in the spectrum of ζ Ursæ Majoris, the familiar "Mizar", were double on one photograph, while certainly single on others. At first, it seemed possible that this doubling might be due to a photographic defect, about which he was so strenuously warned in those days. But there were the double $H\beta$, $H\gamma$, $H\delta$, $H\epsilon$, and even better seen, the fine line *K* of calcium and 4481, due to magnesium. Additional photographs soon confirmed the duplicity, and the first very close binary, since called spectroscopic binary, was discovered. A short time later, Miss Maury found the same peculiarity in the spectrum of β Aurigæ, the second of these systems to be known. Plate XV.

shows photographs of the spectrum of β Aurigæ, with line K single and double. Later, l' Puppis was found to be a close binary by Professor Pickering, μ^1 Scorpii by Professor Bailey, ζ Centauri by Mrs. Fleming, and π Scorpii by the writer. All of these binaries consist of two stars nearly equal in brightness, revolving around a common centre of mass, with rapid velocity, in periods from one to twenty days. There are now more than 300 spectroscopic binaries known, but in most of them one component is so much fainter that its lines are not visible on the photographs and its presence is revealed only by the variable velocity of the system in the line of sight.

One of the most interesting discoveries from the photographs of this memorial was made by Professor Pickering in 1897. He found that the spectrum of a second magnitude star, lettered ζ in the constellation of Puppis, contained, besides the well-known series of hydrogen lines, a second rhythmical series of absorption lines, at first supposed to be due to some substance unknown on the earth, but later assumed to be due to hydrogen under conditions unfamiliar to us. These lines were also found to be present in stars of Class *O*, but as emission lines. They were never produced in the laboratory until 1913, when Professor Fowler succeeded in obtaining them from a mixture of hydrogen and helium in a tube, and they are now generally believed to be due to helium.

The detailed classification of the spectra of the bright southern stars was undertaken by the writer in 1897. The results are published in Volume XXVIII., Part II., of the *Annals*, forming a catalogue of 1122 stars. The photographs for this investigation were taken at Arequipa with the 13-inch Boyden Telescope and have a dispersion somewhat greater than those taken in Cambridge with the 11-inch Draper Telescope. A modification of the system of letters used for the Draper Catalogue was adopted at this time. In various ways, some of the perplexing problems of the early days had already been solved. The stellar sequence was found to be in some respects less complex than was at first supposed.

The appearances for which some of the letters, such as *C*, *D* and *E*, had been assigned, were not confirmed by later and better photographs. Therefore, these letters were dropped from the sequence. In 1891, Professor Pickering wrote, "The principal question now outstanding is to determine what substance or substances cause the characteristic lines in the spectra of stars of the Orion type." This question was settled by Sir William Ramsay's discovery of helium in 1895, and the subsequent identification by Vogel of the lines characteristic of spectra of the Orion type with the new terrestrial element. Hence the so-called Orion stars, which were first known to prevail in that constellation, became helium stars. As it had been clearly proved by the Harvard classification that these spectra precede the Sirian spectra, it was necessary to place the letter *B*, which had been assigned to the Orion stars, before the letter *A*, or to change all the stars previously lettered *A* and *B*. Since several thousand had already been published, the change of the order of the letters was the only practicable course. This inversion of letters is variously regarded by astronomers as an advantage or a drawback to the system. The original letters that persisted were *B*, *A*, *F*, *G*, *K*, *M*, to represent the sequence as far as it was then established. This sequence is shown in Plate XVI. But, as was found in classifying the bright southern stars, the letter *B* could not stand for all the helium stars with their various intensities of lines and differences in number of lines present. Therefore, the writer adopted the plan of dividing into tenths the intervals between spectra represented by successive letters in the sequence. Thus the various subdivisions of *B* stars were called, *B*1 *A*, *B*2 *A*, *B*3 *A*, *B*5 *A*, *B*8 *A*, and *B*9 *A*, later abbreviated to *B*1, *B*2, etc. The width of the lines was also carefully noted in this investigation, as had been done by Miss Maury for the northern stars, and remarks were used to designate those stars whose lines are certainly broad, as α Eridani, or certainly narrow, of division "*c*," as *b* Puppis and ζ^1 Scorpii. Spectra having narrow lines have proved to be of unusual interest, due to the fact that stars with such spectra

have great intrinsic brilliancy and generally very small proper motions.

Therefore a list was made of all spectra known to have narrow lines, and published in Volume LVI., page 162 of the *Annals*. This list includes 96 stars and is probably complete down to the fifth magnitude for both northern and southern stars.

One of the most interesting results of this study of the excellent photographs of the southern stars was the subdivision of the spectra of Class *O* into a progressive series and the discovery of such spectra as that of 29 Canis Majoris which supplied the needed link between spectra of Class *O* and Class *B*. This spectrum resembles Class *O* in the presence of the "Pickering" series, first found in ζ Puppis, called in the Harvard *Annals*, the "additional" hydrogen lines, and also resembles Class *B*0 in the helium and other absorption lines. Thus it happened again that the natural order of the alphabet must be broken, for *O* was then placed before *B* in the stellar sequence. Photographs with the objective prism have not established the position of stars of the fourth type, Class *N*, but Professor Hale's work indicates that they follow Class *M*.

Mrs. Fleming, in her regular survey of the large number of spectra photographed with the various instruments, discovered numerous peculiar and interesting objects. Among them may be mentioned 91 stars of the fifth type, whose spectra consist mainly of bright lines, 69 stars of the helium type with bright lines, 59 gaseous nebulæ, more than 300 variable stars and 10 new stars. The early photographs of variable stars which are bright at maximum, such as o Ceti, *R* Hydræ, *R* Leonis, *U* Orionis, and *R* Cassiopeiæ, showed that their spectra are identical in essential points. Hence, in 1890, Professor Pickering stated that this method could be used for the discovery of such objects, without the necessity of watching the sky. The first variable actually discovered in this way was *R* Cæli, whose variability was confirmed by chart photographs, showing it to be of the seventh magnitude in October, 1889, and only the tenth

magnitude in February, 1890. This method, by which more than 200 variable stars have been discovered on the photographs of the Henry Draper Memorial, is illustrated in Plate XVII, which show the variable *RR* Scorpii, *165030*. The spectrum is of Class *Md*, the banded type, having H_γ and H_δ bright. The chart photographs show the variable when bright and when faint. It has so far been possible to confirm on chart photographs the variability of all stars showing this class of spectrum. A photograph, taken November 3, 1887, of a region in Perseus held a secret of its own for three years, for not until 1890, while making a careful examination of this plate, was it discovered by Mrs. Fleming that the spectrum of one star in this field showed bright lines. No trace of the object could be found on photographs before November, 1887, or after December, 1887. This object is called Nova Persei, No. 1. This discovery was so long after the outburst that very little is known of its history, although the reality of the object was confirmed by several images on chart plates in November and December, 1887. The Draper Memorial photographs continued to yield new stars, as Nova Normæ, discovered in 1893, Nova Carinæ and Nova Centauri in 1895. The latter Nova had a spectrum resembling Class *N*, unlike any other new star so far photographed. This Nova appeared very near the nebula, N. G. C. 5253, and in this respect resembled *S* Andromedæ, which appeared in 1885 in the Great Nebula of Andromeda. Nova Sagittarii, No. 1, appeared in 1897, and Nova Aquilæ, No. 1, in 1898. Six years intervened before Nova Aquilæ, No. 2, was discovered in 1905, and four years more before Nova Aræ and Nova Sagittarii, No. 2, appeared in 1910. Two new stars found by Miss Leavitt, and three by the writer, were not discovered by means of their spectra, but by chart images on plates of the Harvard Map of the Sky. Memoirs on peculiar spectra, spectra of double stars and spectra having bright lines, have been published from time to time as a part of the Henry Draper Memorial.

One disadvantage of spectra obtained with the objective prism is that a comparison spectrum cannot be used, as is

done with the slit spectroscope. As early as 1887, experiments with absorbing mediums, as hyponitric fumes, were made by Professor Pickering, as stated in the First Report of the Henry Draper Memorial. The spectra are photographed so that the starlight passes through a tank containing such a substance, and lines resulting from absorption of this terrestrial medium are scattered among the lines resulting from absorption in the star's atmosphere. It was hoped that accurate measures could thus be made of the stellar lines, referred to some fixed terrestrial lines. But the substances experimented with gave lines which were too wide and ill-defined for satisfactory results. In 1910, Professor Pickering asked Professor Robert W. Wood, of Baltimore, what substance would give the narrowest absorption lines. He replied that the 4272 band of neodymium chloride might answer the purpose, and filled a ray filter with such a solution. By means of this filter, photographs have been made which show a sharp neodymium line among the stellar lines of all the spectra sufficiently bright on the plate. Excellent photographs are now being taken by this method with the 16-inch Metcalf Telescope, from which interesting results are expected.

Lest the spectrographic work of this Memorial should appear to dwarf other investigations, it should be stated that a large number of variable stars have been measured on chart plates, so that their periods and light curves could be determined. The great collection of photographs of the Memorial has also been used for many purposes, and will long be available for objects yet undiscovered. The case of the interesting minor planet Eros, originally called *D Q*, may be cited. When found by Witt in 1898, it was announced to be of the eleventh magnitude, with a remarkable orbit, bringing it nearer at times to the earth than even the planet Mars. By the aid of an ephemeris furnished by Mr. S. C. Chandler, search was made by Mrs. Fleming for this object at the oppositions of 1893 and 1896, but this was very laborious and wearisome owing to the uncertainty of the ephemeris, an error of 1″ in daily motion being sufficient

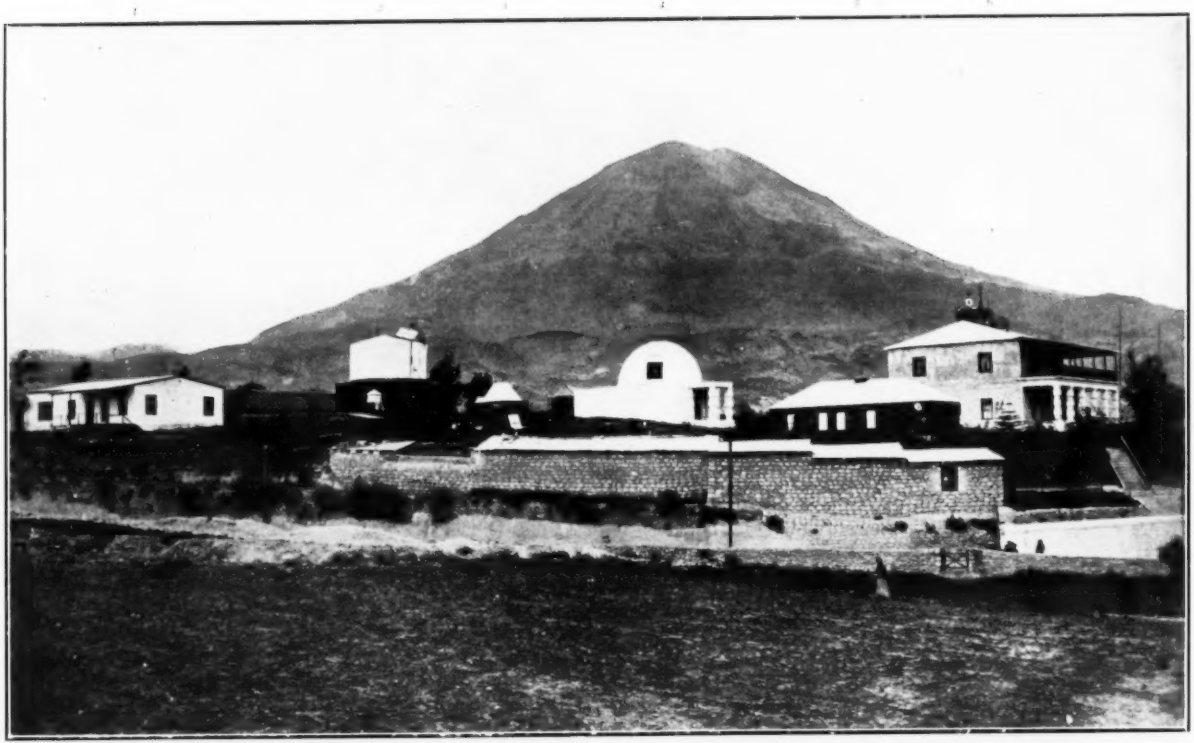
to change the right ascension in 1894 by one half hour. At last it was found on a photograph taken with the 8-inch Draper Telescope on June 5, 1896. With the aid of this position, the ephemeris was corrected by Mr. Chandler, so that Eros was readily picked up on plates taken during the bright opposition of 1893 and 1894. The life history of any other object not too faint, which may yet be discovered, can doubtless be studied as satisfactorily as Eros, on photographs extending as far back as 1890.

Within the last five years, an increased interest has arisen in the classification of stellar spectra. This is mainly due to the discoveries of Professor Campbell and Professor Kapteyn concerning the relation between the radial velocity of the stars and their spectral type, and of Professor Lewis Boss concerning a similar relation between proper motion and spectrum. Professor Campbell announced in 1910 that a comparison of the average motion of 17 km. per second for stars of Classes *G*, *K*, and *M* with the motion of only 7 km. per second for the *B* stars showed unmistakably that the radial velocities of stars are functions of their spectral types. Other interesting relations have also been found, such as a progressive increase in distances between components and in periods of binary stars, according to whether the type of spectrum is early or late.

Since the Draper Memorial collection contains photographs of stellar spectra over the entire sky, observations were commenced by the writer in October, 1911, for a New Draper Catalogue. A regular progress has been made since January, 1912, 5,000 or more stars being classified each month. The classification is now completed for the northern stars, and nearly as far as 18° for the southern. The photographs were taken with the 8-inch telescopes at Cambridge and Arequipa and cover a region about 8° square. A portion of one, taken October 27, 1911, is shown in Plate XVIII. The spectrum of the variable star, *R* Cygni, is seen near the centre of this region, with $H\beta$, $H\gamma$ and $H\delta$ bright. The gaseous nebula, + 50°2869, whose spectrum consists of bright lines, as well as various spectra of classes *A*, *F*, *G*, *K* and *M* are also seen.

HARVARD COLLEGE OBSERVATORY, CAMBRIDGE STATION

(1) The 28-inch Reflector. (2) The 8-inch Draper Telescope. (3) The 24-inch Reflector. (4) The 12-inch Meridian Photometer. (5) The Photographic Library. (6) The 11-inch Draper Telescope. (7) The 15-inch Equatorial. (8) The 15-inch Polar Reflector.



HARVARD COLLEGE OBSERVATORY, AREQUIPA STATION

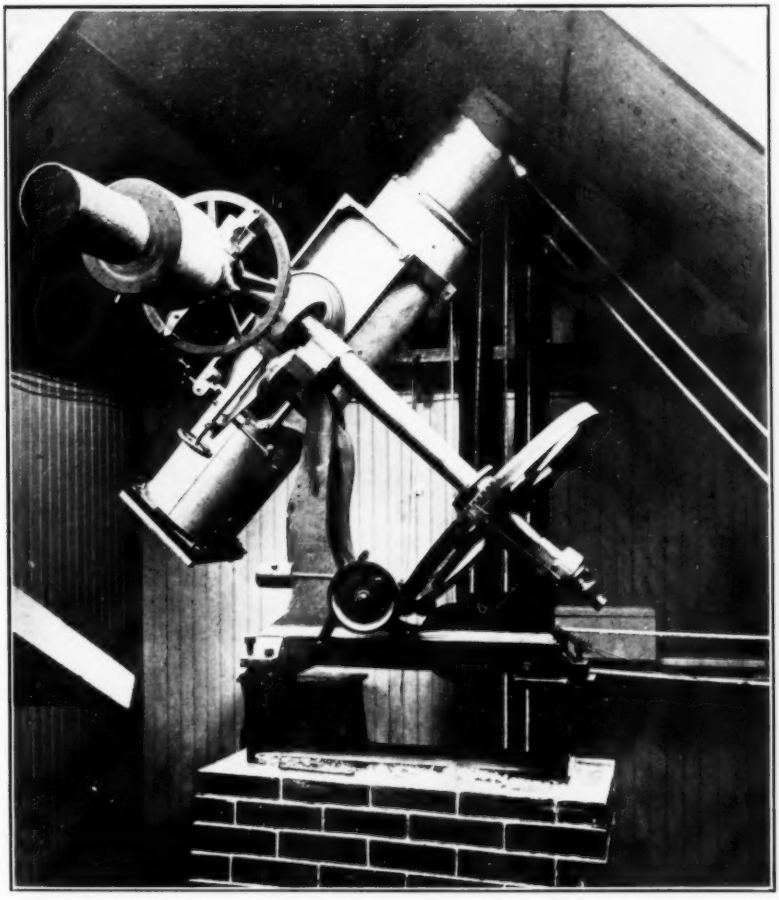
Elevation 8000 feet ; El Misti, 19,200 feet high, in background.

(1) Cottage for Assistants. (2) The 13-inch Boyden Telescope. (3) The 8-inch Bache Telescope.
(4) The 24-inch Bruce Telescope. (5) The Laboratory. (6) The Residence.

Each compartment holds 100 surgical glass plates, 3" × 4" to inches

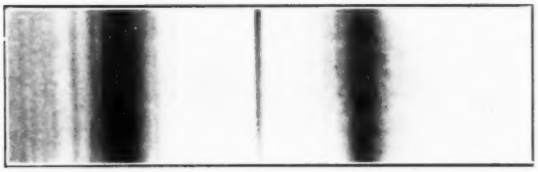
STACK ROOM FOR HOLDING PHOTOGRAPHIC PLATES.
Each compartment holds 100 original glass plates, 8 × 10 inches in size.

PLATE XIV.



THE 8 INCH DRAPER TELESCOPE

PLATE XV.



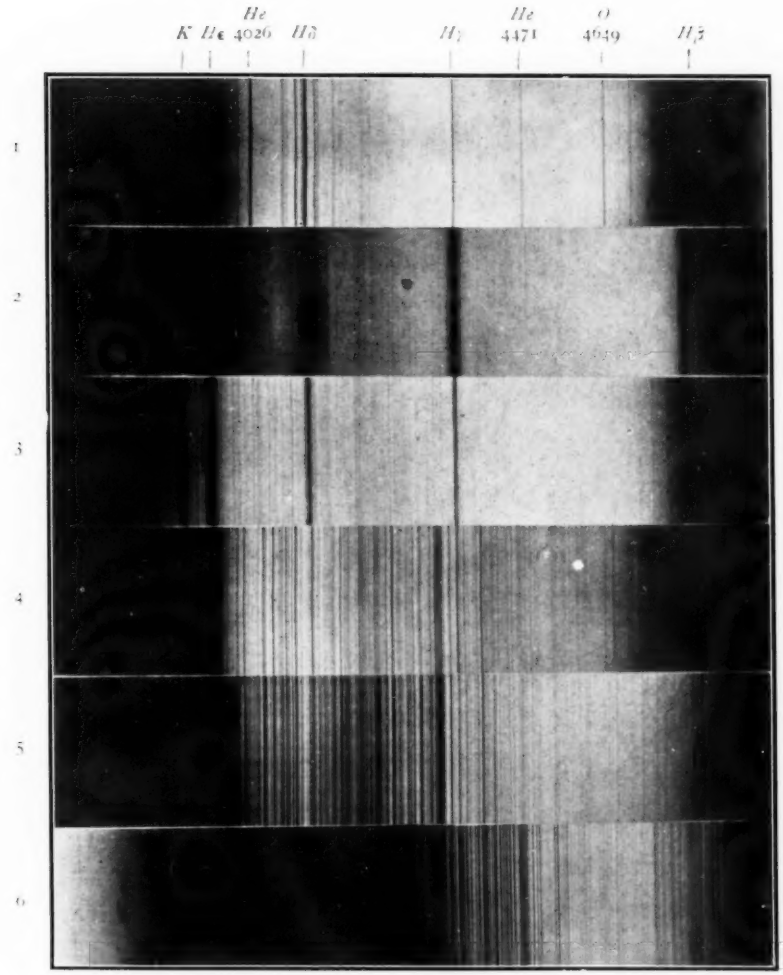
1889, December 30d 17h.6 G.M.T.

1889, December 31d 11h.5 G.M.T.

SPECTRUM OF β AURIGÆ

A typical spectroscopic binary. The *K* line is shown single on December 30, 1889, and double one day later.

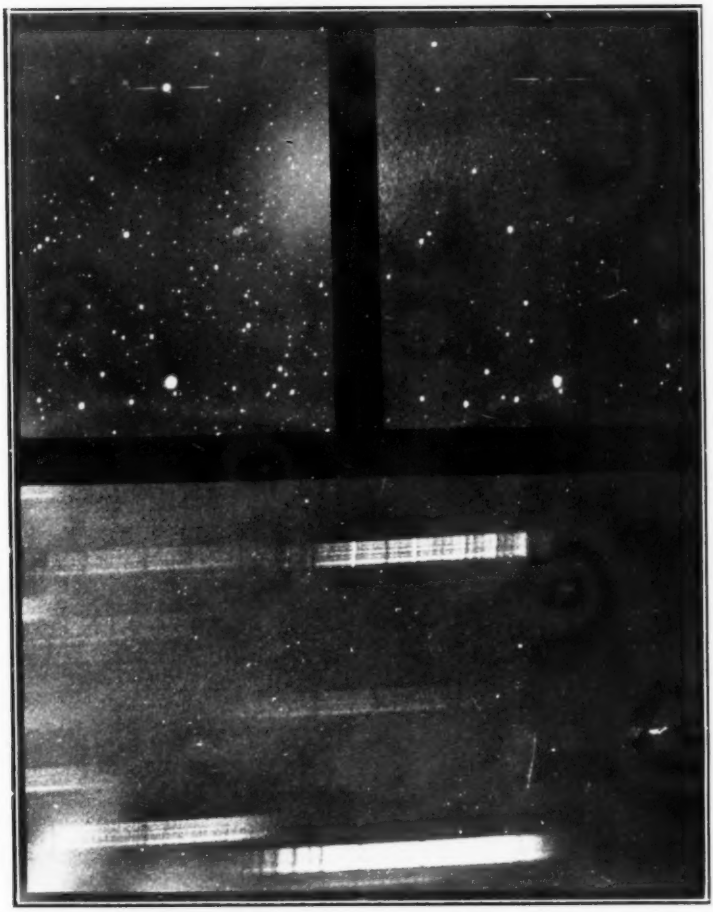
PLATE XVI.



TYPICAL STELLAR SPECTRUM

(1) ε Orionis (Alnitam) ..... *Bo*
(2) α Canis Majoris (Sirius) ..... *Ao*
(3) α Carinæ (Canopus) ..... *Fo*
(4) α Aurigæ (Capella) ..... *Go*
(5) α Bootes (Arcturus) ..... *Ko*
(6) α Orionis (Betelgeuse) ..... *Ma*

PLATE XVII.



METHOD OF DISCOVERING VARIABLE STARS BY BRIGHT LINES IN THEIR SPECTRA

Above, left : photograph showing star *RR* Scorpii bright.
Above, right : photograph showing star faint.
Below : photograph of spectrum.

PLATE XVIII.

N

SPECTRA OF STARS IN REGION OF *R* CYGNI

Exposure, 80 minutes: 8 inch Draper Telescope. Enlarged 1·14 times original.

R Cygni, 49 mm. = 1·9 in. from left edge; 60 mm. = 2·4 in. from bottom.
Gaseous nebula, 17 mm. = 0·7 in. from left; 70 mm. = 2·8 in. from bottom.
Class *M* star, 10 mm. = 0·4 in. from right; 63 mm. = 2·5 in. from bottom.

By the generosity of Mr. George Agassiz, a member of the Board of Visitors, additional assistants have been available to make the identifications and reductions, and the whole work has been placed on a systematic basis. At present 199,196 spectra have been classified. About 150,000 of these are identified, the facts being copied on Library Bureau cards, which are placed in cases in the order of right ascension, where they may be consulted readily for any purpose. The spectra of more than 8,000 stars have already been sent to astronomers in England, Denmark, France, Germany, Holland and Italy, as well as in America, where they are being used for various purposes, such as color index, parallax, radial velocity, proper motion, and double star investigations. It is hoped that the observations for the New Draper Catalogue will be finished in six months, and that printing may be started soon after that time. When the classification is completed, a careful study will be made of the distribution of the various classes of stellar spectra, as a portion of the contribution of the Henry Draper Memorial to the greatest of all investigations, the constitution of the sidereal universe. The problem is so vast that we might despair of any completed result of our tasks were it not for the wonderful correlation revealed during the last five years, among apparently disjointed investigations. That every fact is a valuable factor in the mighty whole should encourage each worker, remembering Argelander's words in 1844, when making an earnest plea for more zealous observations of the variable stars, "Each step brings us nearer the goal, and if we can not reach it, we can at least work so that posterity shall not reproach us for being idle, or say that we have not made an effort to prepare the way for them."

HARVARD COLLEGE OBSERVATORY,
CAMBRIDGE, MASSACHUSETTS,
April 17, 1915.

LOCATION OF EPICENTRES FOR 1914

By Otto Klotz

IN continuation of the series published annually since 1911, the located epicentres for the first half of the year 1914 are herewith issued. That we were able to determine only the epicentres up to July 1 last, is due to the lamentable and insane war now raging in Europe, in consequence of which no reports from the important earthquake stations in Europe have reached us since July, and unfortunately we have in America so very few stations that issue reports that give the necessary data desirable for the location of an epicentre. Harvard and Ottawa, so near each other, require data from distant stations, say along the Pacific coast for seismic triangulation. The war emphasizes this requirement, and it is to be hoped it will bear fruit. The extent of America is great enough to make us, if necessary, independent of the rest of the world, provided we have the requisite stations, for locating any decent quake, that is, a quake that shakes the world.

The locations have been made by the stereographic method, wherewith our published tables for facilitating the plotting, have been utilized.

In the following table column 1 gives the date of the quake; column 2 gives the stations utilized if a satisfactory epicentre has been obtained, that is, if the intersection of the arcs has been at or very near a common point; column 3 then gives the geographical co-ordinates of such epicentre. In case the intersections are unsatisfactory and far apart, due of course to erroneous interpretation of some or all of the seismograms considered, then "no location" is entered; column 4 gives the epicentre as found in the reports received; while column 5 gives the available data for computing or plotting the epicentre.

It may be noted that we confine ourselves to quakes of

which some record has been obtained at Ottawa, not necessarily all the phases, *P*, *S*, *L*.

It is gratifying to note that year by year there is an improvement in the accuracy of the time record at many stations, brought about largely by the availability of wireless time signals sending out observatory time.

The stereographic plotting has been done by E. A. Hodgson of our office.

LOCATION OF EPICENTRES, 1914

Date	Stations	Epicentre	Other Locations	Remarks
1914				
Jan. 20		No Location	Trieste	Innsbruck = 8500
			ϕ = 52·9 N.	Pulkowa = 6700
			λ = 159·6 E.	Konigsberg = 7375
				Budapest = 8220
			Tashkent	Vienna = 8250
			ϕ = 56·7 N.	Zagreb = 8550
			λ = 156·8 E.	Uccle = 8300
				Lemberg = 8060
			Ekaterinburg	Aachen = 8250
			ϕ = 56·9 N.	Belgrade = 8480
			λ = 154·2 E.	Graz = 8400
				Czernowitz = 7800
			Tiflis	Athens = 110
			ϕ = 46·7 N.	Trieste = 8550
			λ = 172·6 E.	Tashkent = 6620
			and also	Baku = 7410
			ϕ = 32·6 N.	Ekaterinburg = 5680
			λ = 71·7 E.	Tiflis = 8920
				Irkutsk = 3400
Jan. 30	Pulkowa	Φ = 34·0 S.	Pulkowa	Ottawa = 8750
		λ = 70·0 W.	ϕ = 12·0 S.	Harvard = 7325
	Göttingen	Location	λ = 137·0 E.	Innsbruck = 9200
		doubtful	and also	St. Louis = 8300
			ϕ = 20·0 S.	Konigsberg = 8700
			λ = 62·0 W.	Budapest = 8570
			Felt at	Vienna = 9400
			Victoria,	Zagreb = 9600
			Talca,	Lemberg = 10000
			Concepcion,	Aachen = 8300
			Mendosa, and	Göttingen = 8600
			Valparaiso.	Belgrade = 8810
			Shide	Graz = 9160
			ϕ = 34·1 S.	Athens = 8800
			λ = 66 W.	Pulkowa = 12060
			Tashkent	Trieste = 8200
			ϕ = 27 S.	La Paz = 2080
			λ = 67 W.	Naples = 8000

LOCATION OF EPICENTRES, 1914

Date	Stations	Epicentre	Other Locations	Remarks
Jan. 30		No Location.		Ottawa = (9000) Graz = 8500 Tashkent = 15500 Tiflis = 9780 La Paz = 2070
Feb. 10		Local quake.		Ottawa = 120 Harvard = 435 St. Louis = 900
Feb. 28	Ottawa, Pulkowa, Vienna, Harvard.	ϕ = 20·0 N. λ = 70·9 W.	Harvard gives the West Indies as the Epicentre, confirming the location found	Ottawa = 2800 Harvard = 2470 Vienna = 8300 Graz = 9000 Pulkowa = 8700 Tashkent = 7300 La Paz = 6950
Mar. 6	Innsbruck, Budapest, Uccle, Lemberg, Pulkowa, Belgrade Czernowitz, Trieste, Baku, Ekaterinburg Irkutsk.	ϕ = 53·5 N. λ = 158·0 E.	Königsberg Kamchatka Pulkowa ϕ = 53·0 N. λ = 158·0 E. Tashkent ϕ = 48·8 N. λ = 158·2 E. Ekaterinberg ϕ = 51·6 N. λ = 157·0 E.	Ottawa = 10000 Innsbruck = 9680 Budapest = 9180 Vienna = 8300 Pulkowa = 6620 Uccle = 8400 Lemberg = 7900 Strassburg 3000 Belgrade = 8250 Czernowitz = 8000 Trieste = 8600 Baku = 7750 Ekaterinburg = 5800 Irkutsk = 3515
Mar. 13	Ottawa, Strassburg, Pulkowa.	ϕ = 28·2 N. λ = 110·1 W. Location doubtful	Pulkowa. ϕ = 19·0 N. λ = 89·0 W. or ϕ = 16·0 N. λ = 92·0 W.	Ottawa = 3450 Uccle = 8750 Strassburg = 9400 Pulkowa = 9690
Mar. 14	Ottawa, Innsbruck, Königsberg, Budapest, Vienna, Uccle, Lemberg, Aachen, Göttingen, Laibach, Belgrade,	ϕ = 39·0 N. λ = 139·6 E.	Epicentre known to be in Japan. Pulkowa ϕ = 39·2 N. λ = 139.3 E. Trieste ϕ = 39·8 N. λ = 141·4 E.	Ottawa = 10200 Innsbruck = 9150 Königsberg = 8000 Budapest = 8790 Vienna = 8400 Uccle = 9120 Lemberg = 8700 Aachen = 9050 Göttingen = 9000 Laibach = 9050 Belgrade 8970

Location of Epicentres, 1914

Date	Stations	Epicentre	Other Locations	Remarks
Mar. 14	Graz, Czernowitz, Athens, Pola, Pulkowa, Trieste, Tashkent, Ekaterinburg, Tiflis, Irkutsk, Zi-Ka-Wei.		Ekaterinburg ϕ = 40·3 N. λ = 141·3 E. Tiflis ϕ = 46·2 N. λ = 148·6 E. Irkutsk ϕ = 38·5 N. λ = 138·0 E.	Graz = 9000 Czernowitz = 8300 Athens = 9280 Pola = 9200 Pulkowa = 7280 Trieste = 9100 Tashkent = 5910 Baku = 7469 Ekaterinburg = 5480 Tiflis = 7690 Irkutsk = 3000 Zi-Ka-Wei = 2000 Ksara = 10300
Mar. 18	Ottawa. Innsbruck, Königsberg, Budapest, Vienna, Zagreb, Uccle, Lemberg, Aachen, Göttingen, Laibach, Belgrade, Graz, Czernowitz, Trieste, Tashkent, Ekaterinburg, Tiflis, Irkutsk.	ϕ = 54·0 N. λ = 105·5 E.	Tashkent ϕ = 52·7 N. λ = 159·0 E. Ekaterinburg ϕ = 58·0 N. λ = 105·2 E. Tiflis ϕ = 53·0 N. λ = 158·0 E. Irkutsk ϕ = 53·4 N. λ = 105·8 E Pulkowa ϕ = 53·3 N. λ = 159·4 E	Ottawa = 7550 Innsbruck = 8500 Königsberg = 7560 Budapest = 8130 Vienna = 8100 Zagreb = 8380 Uccle = 8200 Lemberg = 10000 Aachen = 8850 Göttingen = 8560 Laibach = 8100 Belgrade = 8730 Graz = 8400 Czernowitz = 7800 Athens = 8120 Trieste = 8530 Tashkent = 6500 Baku = 7850 Ekaterinburg = 5610 Tiflis = 7890 Irkutsk = 4000
Mar. 18	Ottawa, Innsbruck, Budapest, Zagreb, Strassburg, Göttingen, Laibach, Belgrade, Graz, Czernowitz, Pulkowa, Trieste, Tashkent, Ekaterinburg, Tiflis, Irkutsk.	ϕ = 55·0 N. λ = 161·0 E.	Pulkowa ϕ = 54·0 N. λ = 156·0 E. Ekaterinburg ϕ = 54·0 N. λ = 160·3 E.	Ottawa = 7400 Innsbruck = 8700 Budapest = 8300 Zagreb = 8200 Strassburg = (8500) Göttingen = 8400 Laibach = 7600 Belgrade = 8200 Graz = 8400 Czernowitz = 7803 Pulkowa = 6520 Trieste = 8640 Tashkent = 6430 Ekaterinburg = 5650 Tiflis = 7890 Irkutsk = 4050

LOCATION OF EPICENTRES 1914

Date	Stations	Epicentre	Other Location	Remarks
Mar. 21	Ottawa, Tashkent, Baku.	ϕ = 14·0 N. λ = 50·3 W. Location doubtful	Tashkent ϕ = 27·0 N. λ = 84·0 W.	Ottawa = 4300 Pulkowa = 10140 Tashkent = 11220 Baku = 8640
Mar. 27	Ottawa, Zagreb, Laibach, Belgrade, Graz, Pulkowa, Tashkent, Tiflis, Irkutsk.	ϕ = 55·0 N. λ = 106·3 E.	Pulkowa ϕ = 53·1 N. λ = 158·4 E. Tashkent ϕ = 53·3 N. λ = 104·2 E. Ekaterinburg ϕ = 52·2 N. λ = 159·7 E. Tiflis ϕ = 58·8 N. λ = 159·3 E. Irkutsk ϕ = 54·3 N. λ = 172·1 E.	Ottawa = 6200 Vienna = 10000 Zagreb = 7280 Laibach = 8000 Belgrade = 4700 Graz = 8420 Czernowitz = (9000) Pulkowa = 6640 Tashkent = 6730 Baku = 7950 Ekaterinburg 5840 Tiflis = 7930 Irkutsk = 4315
Mar. 30	Budapest, Vienna, Uccle, Strassburg, Aachen, Göttingen, Belgrade, Graz, Czernowitz, Trieste, Irkutsk.	ϕ = 40·0 N. λ = 136·4 W. Location doubtful	Athens ϕ = 19·0 N. λ = 96·0 W.	Ottawa = 3800 Konigsberg = 10250 Victoria = 4800 Budapest = (10400) Vienna = 9600 Uccle = 9500 Strassburg = 9500 Aachen = 9400 Göttingen = 9600 Laibach = 9100 Belgrade = 10420 Graz = 9170 Czernowitz = 9900 Athens = 9560 Pulkowa = 10000 Trieste = 9500 Tashkent = 16000 Irkutsk = 8250 Toronto = 2725 La Paz = 4250
Apr. 9		No Location		Ottawa = 9600 Harvard = 7450 Strassburg = (16000) Belgrade = 17000 Graz = 16000 Pulkowa = 14000

Location of Epicentres, 1914

Date	Stations	Epicentre	Other Locations	Remarks
Apr. 11	Sydney, Tashkent, Ekaterinburg, Irkutsk, Zi-Ka-Wei.	Φ = 9·9 S. λ = 161·4 E.	Sydney ϕ = 12·5 S. λ = 165·0 E. Pulkowa ϕ = 16·0 S. λ = 168·0 E. Ekaterinberg ϕ = 9·9 S. λ = 157·2 E. Tashkent ϕ = 5·0 S. λ = 154·0 E. Irkutsk ϕ = 6·2 N. λ = 169·2 E.	Ottawa = 12000 Harvard = 12000 Victoria = 14000 Aachen = 10000 Laibach = 10000 Belgrade = 18000 Sydney = 2770 Graz = 9000 Czernowitz = 10000 Pulkowa = (14200) Tashkent = 10800 Ekaterinburg = 11300 Irkutsk = 8900 Zi-Ka-Wei = 6200
Apr. 20	Ottawa, Harvard, Innsbruck, Konigsberg, Vienna, Zagreb, Strassburg, Aachen, Gottingen, Laibach, Graz, Pulkowa, Ekaterinburg Toronto, La Paz.	Φ 6·3 N. λ 78·7 W.	Budapest ϕ = 48·3 N. λ = 17·3 E. Pulkowa ϕ = 7·6 N. λ = 79·1 W. Erkaterinburg Φ = 5·7 N. λ = 72·3 W.	Ottawa = 4450 Harvard = 4100 Innisbruck = 9700 Konigsberg = 9440 Budapest = 160 Vienna = 9950 Zagreb = 9500 Strassburg = 9500 Aachen = 9150 Gottingen = 9300 Laibach = 9100 Belgrade = 9400 Graz = 9410 Pulkowa = 10340 Tashkent = 13300 Ekaterinburg = 11850 Toronto = 4440 La Paz = 2580 Frankfurt a. M. 9500
Apr. 24		No Location		Ottawa = 3500 Santa Clara = 343
May 19		No Location	Pulkowa ϕ = 1·0 S. λ = 154·0 E. Baku ϕ = 0·8 S. λ = 150·1 E. Irkutsk ϕ = 5·0 S. λ = 153·1 E.	Ottawa = 4400 Graz = 9000 Pulkowa = 11880 Baku = 10130 Irkutsk = 7850 La Paz = 2980

LOCATION OF EPICENTRES, 1914

Date	Stations	Epicentre	Other Locations	Remarks
May 26	Ottawa, Harvard, Königsberg, Vienna. Aachen, Pulkowa, Ekaterinburg, Irkutsk.	ϕ = 15·0 N. λ = 166·6 E. Location doubtful	Pulkowa ϕ = 0·3 S. λ = 138·8 E. Ekaterinburg ϕ = 1·0 S. λ = 141·0 E. Irkutsk ϕ = 1·1 S. λ = 143·0 E.	Ottawa = (9200) Harvard = 12000 Innsbruck = 10150 Königsberg = 10500 Vienna = 12300 Zagreb = 10000 Aachen = 12000 Graz = 9570 Athens = 5520 Pola = 10000 Pulkowa = 10810 Trieste = 8730 Ekaterinburg = 9520 Irkutsk = 6790 La Paz = 17000 Ksara = 10000
May 28	Ottawa, Harvard, Innsbruck, Königsberg, Budapest, Vienna, Zagreb, Aachen, Laibach, Graz, Czernowitz, Pulkowa, Trieste, La Paz.	ϕ = 11·5 N. λ = 78·6 W. "Near Panama"	Pulkowa ϕ = 15·1 N. λ = 84·8 W.	Ottawa = 3800 Harvard = 3580 Innsbruck = 9100 Königsberg = 9460 Budapest = 9500 Vienna = 9460 Zagreb = 9500 Aachen = 8850 Laibach = 9300 Graz = 9350 Czernowitz = (10000) Pola = 700 Pulkowa = 9890 Trieste = 9100 Tiflis = 9650 and = 8330 (regarded as two) La Paz = 3100
May 28	Ottawa, Pola, Trieste, La Paz	ϕ = 17·0 N. λ = 92·5 W.		Ottawa = 3600 Laibach = 8600 Pola = 9800 Trieste = (9400) La Paz = 4700
May 29	Innsbruck, Königsberg, Budapest, Vienna, Zagreb, Graz, Czernowitz, Athens, Pola,	ϕ = 1·0 N. λ = 96·2 E.	Pulkowa ϕ = 1·0 N. λ = 95·6 E. Ekaterinburg ϕ = 1·9 N. λ = 99·8 E.	Ottawa = 5600 Innsbruck = 9600 Königsberg = 9100 Budapest = 9000 Vienna = 9200 Zagreb = 9300 Graz = 9250 Czernowitz = 8600 Athens = 8500

Location of Epicentres, 1914

Date	Stations	Epicentre	Other Locations	Remarks
May 29	Pulkowa, Trieste, Ekaterinburg, Irkutsk, Ksara.		Irkutsk φ = 1·8 N. λ = 114·1 E.	Pola = 9250 Pulkowa = 8580 Trieste = 9400 Ekaterinburg = 7020 Irkutsk = 5800 Ksara = 7200 to = 7700
May 31		No Location		Ottawa = 2300 Laibach = 5000 Tiflis = 1060
June 20	Ottawa, Innsbruck, Czernowitz.	φ = 24·7 N. λ = 166·0 E.	Pulkowa φ = 16·0 S. λ = 167·0 E.	Ottawa = 10400 Harvard = 12400 Innsbruck = 11450 Czernowitz = (11000) Athens = 2220 Pulkowa = 14000
June 25	Ottawa, Aachen, Graz, Czernowitz, Pola, Pulkowa, Trieste.	φ = 37·5 N. λ = 135·6 W. Location doubtful	Pulkowa φ = 2·3 S. λ = 100·3 E. Naples "Japan"	Ottawa = 5000 Aachen = 9400 Graz = 9350 Czernowitz = 9200 Athens = 8850 Pola = 9400 Pulkowa = 9130 Trieste = 9300

Dominion Observatory,
Ottawa, Canada

TWO SPECTROSCOPIC BINARY ORBITS*

By Reynold K. Young

I. ω Cassiopeiæ

THE binary character of ω Cassiopeiæ ($\alpha = 1^h\,49^m{\cdot}0$, $\delta = +68^\circ$ 15′, 1910, Mag. 5·2 Type *B* 9) was announced by Adams in the *Astrophysical Journal* in 1912. Fifty-two spectrograms, taken with a one-prism spectrograph at this observatory during 1913-14-15 have been used in determining an orbit. The velocity curve is shown in Figure 1.

The spectrum shows three fairly measurable lines, calcium *K*, hydrogen *Hγ*, and magnesium λ4481. Beside these the

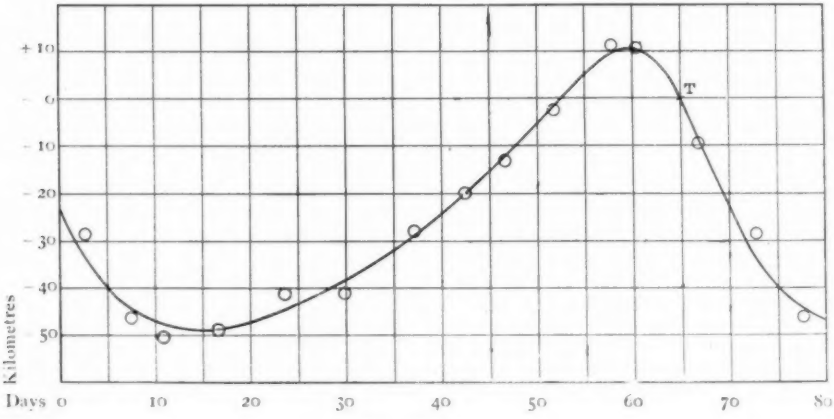


FIGURE 1.

VELOCITY CURVE OF ω CASSIOPEIÆ

prominent helium lines, the high temperature silicon lines (λλ4128, 4131) and a few others were sometimes measured. The

*These orbits will appear in more detail in the Dominion Observatory Publications.

elements given below are the result of a least square solution. The probable error of a single observation is 2·8 kilometres.

$$P = 69{\cdot}92 \text{ days}$$
$$e = 0{\cdot}30 \pm 0{\cdot}024$$
$$\omega = 49°{\cdot}97 \pm 4°{\cdot}08$$
$$K = 29{\cdot}64 \text{ km.} \pm 0{\cdot}73$$
$$\gamma = -24{\cdot}82 \text{ km.} \pm 0{\cdot}10$$
$$T = \text{Julian Day } 2{,}420{,}426{\cdot}02 \pm 0{\cdot}67 \text{ days.}$$
$$a \sin i = 27{,}190{,}000 \text{ km.}$$
$$\frac{m_1^3 \sin^3 i}{(m + m_1)^2} = 0{\cdot}164 \times \text{sun.}$$

II. 23 Cassiopeiæ

The binary character of 23 Cassiopeiæ ($\alpha = 0^h\ 41^m{\cdot}1$ $\delta = +74°\ 18'$, 1900, Mag. 5·39 Type *B*8) was announced by Adams in the *Astrophysical Journal* in 1912. Sixty-one spectrograms have been used in determining an orbit. The velocity curve is shown in Figure 2.

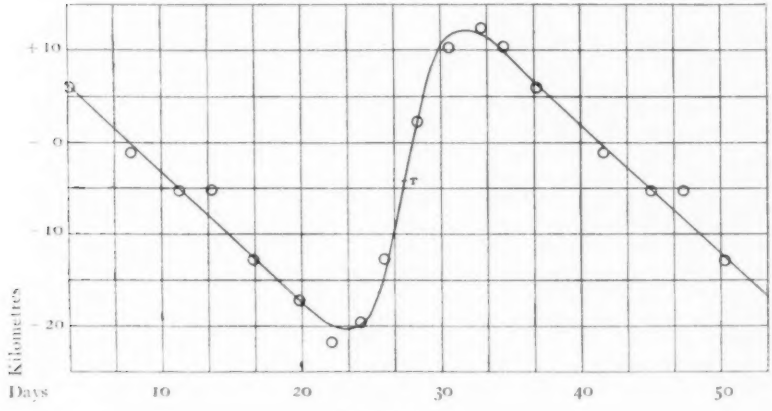


Figure 2

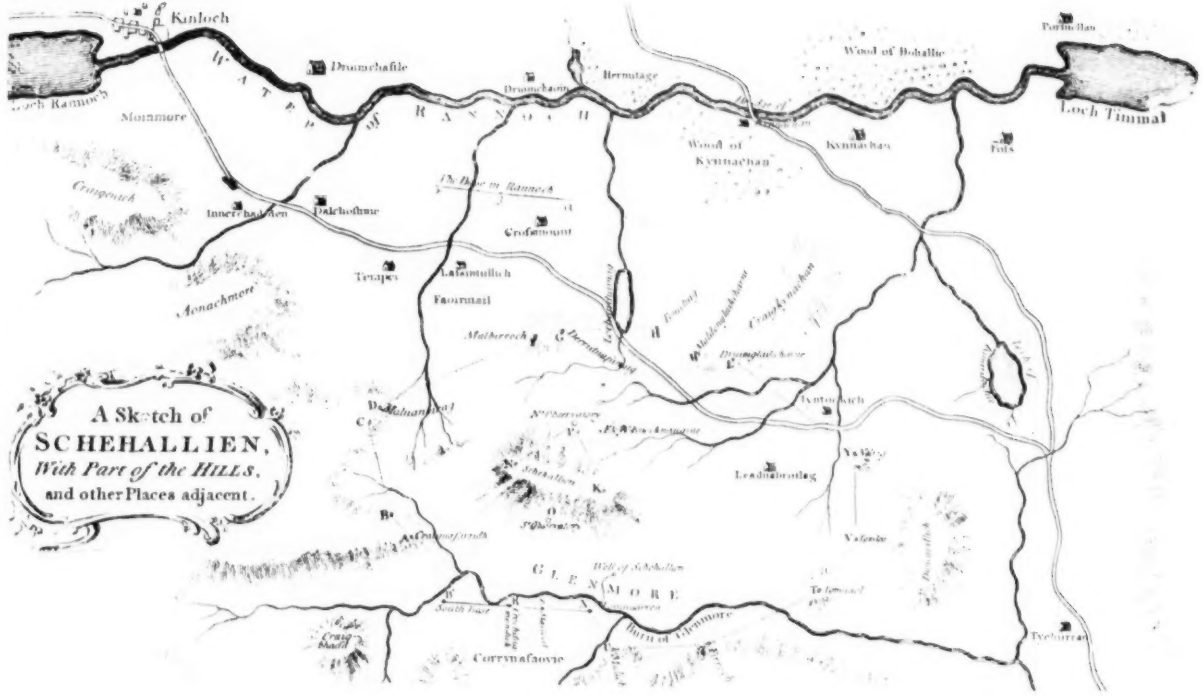
Velocity curve of 23 Cassiopeiæ

The principal lines in the spectrum are calcium *K*, and hydrogen *Hγ*. These two lines were as a rule very good. The

helium lines were too faint to measure. Hydrogen $H\delta$ and the high temperature silicon lines λλ4128, 4131 were sometimes measured. The final elements with their probable errors follow. The probable error of a single observation is 3·4 kilometres.

$$P = 33{\cdot}75 \text{ days.}$$
$$e = 0{\cdot}405 \pm 0{\cdot}026$$
$$\omega = 269°{\cdot}71 \pm 4{\cdot}10$$
$$K = 16{\cdot}32 \text{ km.} \pm 0{\cdot}50$$
$$\gamma = 4{\cdot}06 \text{ km.} \pm 0{\cdot}34$$
$$T = \text{Julian Day } 2{,}420{,}577{\cdot}41 \pm 0{\cdot}27$$
$$a \sin i = 7{,}020{,}000 \text{ km.}$$
$$\frac{m_1^3 \sin^3 i}{(m + m_1)^2} = 0{\cdot}0121 \times \text{sun.}$$

DOMINION OBSERVATORY,
OTTAWA, CANADA.



MAP TO ILLUSTRATE MASKELYNE AND HUTTON'S DETERMINATION OF THE EARTH'S DENSITY

Journal of the Royal Astronomical Society of Canada, 1915

SCHEHALLIEN

By Otto Klotz

IN these days of restless scientific enquiry and research, it may be profitable to turn back the hands of time and survey the beginnings of some important problem. We transplant ourselves to the last quarter of the 18th century when the question of the mean density of the earth engaged the attention of astronomers and mathematicians. Local deflection of the plumb line was already an established fact, so that a very plausible method presented itself of determining the mean density of the earth by comparison of the observed deflection from astronomical observations for latitude, with the theoretical deflection determined from the attractive force of the attracting hill, on opposite sides of which the astronomic observations were made. Maskelyne was at this time Astronomer Royal. For carrying out this investigation of the mean density of the earth Schehallien was selected as the attracting hill. Maskelyne says of it, *Philosophical Transactions* for 1775, pp. 502-503: "Fortunately, however, Perthshire afforded us a remarkable hill, nearly in the centre of Scotland, of sufficient height, tolerably detached from other hills, and considerably larger from east to west than from north to south, called by the people of the low country, Maiden-pap, but by the neighboring inhabitants Schehallien; which, I have since been informed, signifies in the Erse language, Constant Storm: a name well adapted to the appearance which it so frequently exhibits to those who live near it, by the clouds and mists which usually crown the summit."

The survey of Schehallien in Perthshire was carried out in 1774, 1775, and 1776 under the direction of Maskelyne, and a report thereof submitted to the Royal Society by Charles Hutton, May 21, 1778, from which the following notes have been abstracted.

The principle underlying this attempt to obtain a value of the mean density of the earth was simple; zenith distance observations were to be taken at points directly north and south of the hill, hence the attractive force of the hill on the vertical would have opposite signs for the north and south observations. The two observation points or observatories (temporary) were connected by triangulation, hence their actual distance apart, projected on to a common meridian was known, and this was then compared with the difference resulting from astronomic observations. This latter of course involved the deviation or attraction due to the hill, and hence a relative measure of the attraction of the hill to that of the earth was obtained. It was necessary to know the volume of the hill in the first place, and finally its mass. To determine the former a linear survey was made around the foot of the hill, occupying seventeen stations, besides a base line on the south side and one on the north side of the hill, and also the two observatories and two points on the crest of the hill, as well as a few subsidiary points were occupied. See accompanying map.

From each of these points both horizontal and vertical angles were read on all other visible stations. A word about the measurement of the base-lines. Two (wooden?) rods were used each approximately 20 feet in length. Each was compared with a standardized brass rod three feet long, and the comparison was corrected for temperature of the brass rod, and its wear —one five-hundredth of an inch. The standard temperature was 62° F, and the co-efficient of expansion used was 29·2,700,000, or ·0000107, a co-efficient that agrees very well with the present one. The corrected base *RB''* was found to be 3011·417 feet long. A part of this base-line 2839·3 feet was measured with a tape (web), and found to be 2844·8 feet, that is, 5½ feet longer than with the rods. The difference is accounted for in a small degree "to the unstable state of the wooden stands used in the first quarter of the base; but the greater part of this difference is more likely to be owing to the uncertain way of measuring with a tape, which, to say nothing of the ground not being quite

level, is liable to be stretched more or less in length with different degrees of tension, and to be variously warped in length by moisture." One would expect that by stretching the tape the measured distance therewith would in consequence be shorter, and not longer as found.

The above difference of about 1 in 500 seems very large, considering the care that was attempted. On the other base $\alpha\,\beta\,\gamma$ the difference between rod and chain (a chain was used instead of a tape) measurements was not so large, the chain giving better results than the tape. The actual difference in 4183·558 feet was 1·558 feet, for the part $\alpha\,\beta$ of $\alpha\,\beta\,\gamma$, which latter was 5895·399 feet long.

The angles were measured with a theodolite, and most of the angles, both horizontal and vertical, recorded to full minutes only. For many of the angles the instrument was reversed and hence two readings obtained, so that frequently the resulting angle is recorded to fractional parts of a minute, *e.g.* ¼, ⅓, ½, ⅔, ¾, ⅙, ⅝. Hutton had now measured two base lines, one to the south, the other to the north of Schehallien; and he had all his angles measured. The problem of "adjustment of triangulation" confronted him. We shall let him speak: "Having now obtained to a great degree of accuracy, the measured lengths of two lines which were to serve as bases for all the future calculations, the next consideration was how to make the properest use of them. Every other line or distance, drawn or conceived to be drawn, must be calculated from them by the help of the angles observed either at their extremities or at all the other points and stations in the survey and plan. As these two bases are situated in the low parts of the country, from whence but a very few of the other principal stations are visible, one method evidently is to compute immediately from these bases such of the great lines in the survey whose extremities are visible from them, and then from these calculated lines to compute others next to them, and so on quite around and within the whole figure. In this manner several values of each line will arise, both from the double computations by the two measured bases, and from the

various sets of triangles which can be formed from the very numerous horizontal angles which were observed at the several stations. But in this mode of computation, after great labor and pains, I had frequently the mortification to find that the several values of the same lines would differ greatly one from another, that I was very often doubtful whether I could rely on any of them, or even on the mean among them all. These differences arose from the small errors in the observed angles, which in some degree are unavoidable ; and indeed they were so small, that the sum of the angles of the several triangles which were used in the calculation seldom differed by more than a minute or two from 180°. But in a long connected chain of triangles, dependent on one another, the effects of such small errors at length become too great to be tolerated in a computation requiring much accuracy. Another method is, first to compute from both bases the length of the line $K'N$ extended along the ridge of the hill from east to west, and from it, as a secondary base, compute all the other lines in the plan. This method admits of much more accuracy than the former, supposing this secondary base to be truly assigned ; because that, from the elevated and central position of this line, all or most of the other points in the survey are visible from one or both of its extremities, by which it happens that the other lines are mostly determinable from it alone, without so close a connection with one another as in the other method of computation. By both of these methods then, and by all the triangles furnished by each of them, I computed all the principal lines in the plan, and either took a mean among the several values of each, or else selected out of them such one as from various circumstances I judged it safest to rely upon, as nearest the truth. The mean among a great number of ways of computing from the south base gives the horizontal distance from K' to $N = 4052{\cdot}2$, and the mean of all the results from the north base of $\alpha\beta\gamma$ gives $K'N = 4058{\cdot}9$, and the mean between these two gives 4055·5 for the mean distance of K' and N. And this value of $K'N$ was used in computing most of the other lines." Although it is 140 years since this survey was made, and making

due allowance for possible crudeness of instruments and methods, yet considering the care taken in the work it is surprising to see such discordances and differences in the results. Take the last example of the subsidiary base $K'N$; the difference in length is equivalent to 1 in 600, which is not much better than pacing.

Very many points were observed on, both horizontally and vertically, "so that the number of triangles, whose numerical solutions have been performed in the course of this business, amounts to several thousands."

It may be mentioned that Schehallien (Schiehallion) is given by the *Britannica* as 3547 feet above sea-level. In the tables the greatest height of one station above another is found to be 2013 feet.

For computation of the attraction in the area under consideration the ground was divided by 20 cencentric, equidistant circles, 666⅔ feet apart, or to a distance of about 2½ miles, about each observatory. Each quadrant was divided into 12 parts or sectors by lines or radii forming with the meridian angles whose sines are in arithmetical progression, *i. e.*, $^1/_{12}$, $^2/_{12}$, ... $^{12}/_{12}$ of radius; this was done for simplification in computation. There were thus 960 parts or compartments about each observatory, or nearly 2000 in all to be computed. A horizontal plane was supposed to pass through each observatory and the mass above and below in each compartment was considered and its gravitational effect at the respective observatory tabulated. It was found that the attraction at the north observatory was to that of the south observatory as 70 to 89, or as 7 to 9 nearly, due to difference of distribution of the mass. These figures 70 and 89 represent respectively what Hutton calls "effective sum of the sines" expressed in feet at the two observatories, (69·967 feet and 88·644 feet). Their sum 158·611 multiplied by the width 666⅔ feet of the circular bands and by $^1/_{12}$ gives "8811⅔ nearly, and is the sum of the two opposite attractions made by the hill, etc., at the two observatories." This number is then compared with the total attraction of the earth, expressed by $\frac{2}{3}\pi d$, where

d is the diameter of the earth. As πd represents the circumference, the comparison is with $\frac{2}{3}$ circumference. This last quantity Hutton gives as 87522720 feet, "for the measure of the attraction of the earth." The ratio of the latter to $8811\frac{2}{3}$ is as 9933 to 1, "on supposition that the density of the matter in the hill is equal to the mean density of that in the whole earth."

"But the Astronomer Royal found, by his observations, that the sum of the deviations of the plumb line, produced by the two contrary attractions, was 11·6 seconds. From hence it is to be inferred, that the attraction of the earth is actually to the sum of the attractions of the hill, nearly as radius to the tangent of 11·6 seconds, that is, as 1 to ·000056239, or as 17781 to 1; or as 17804 to 1 nearly, after allowing for the centrifugal force arising from the rotation of the earth about its axis." Hence "the two proportions compared must give the ratio of their densities, which is that of 17804 to 9933, or almost as 9 to 5. And so much does the mean density of the earth exceed that of the hill." Of this result Hutton says: "I think we may rest satisfied, that this proportion is obtained to a considerable degree of proximity, probably to within the fiftieth part, if not the hundredth part of its true magnitude." Continuing we quote: "Another question, however, still arises, namely, what is the density of the matter in the hill? . . . . . It is probable, therefore, that we shall not greatly err, if we assume the density of the hill equal to that of common stone; which is not much different from the mean density of the whole matter near the surface of the earth, to such depths as have actually been explored either by digging or boring. Now the density of common stone is to that of rain water as $2\frac{1}{2}$ to 1; which being compounded with the proportion of 9 to 5 above found, there results the ratio of $4\frac{1}{2}$ to 1 for the ratio of the densities of the earth and rain water: that is to say, the mean density of the whole earth is about $4\frac{1}{2}$ times the density of water."

Thus was brought to a close this first and classic determination of the density of the earth. It may be interesting to quote a page following the above: "To what useful purposes the

knowledge of the mean density of the earth, as above found, may be applied, it is not my business here to show. I shall, therefore, put an end to this paper with a reflection or two on the premises before delivered. Sir Isaac Newton thought it probable, that the mean density of the earth might be five or six times as great as the density of water; and we have now found, by experiment, that it is very little less than what he had thought it to be: so much justness was even in the surmises of this wonderful man! Hense, as the mean density of the whole earth is about double that of the general matter near the surface, and within our reach, it follows, that there must be somewhere within the earth, towards the more central parts, great quantities of metals, or such like dense matter, to counterbalance the light materials, and produce such a considerable mean density. If we suppose, for instance, the density of metal to be 10, which is about a mean among the various kinds of it, the density of water being 1, it would require sixteen parts out of twenty-seven, or a little more than one-half of the matter in the whole earth, to be metal of this density, in order to compose a mass of such mean density as we have the earth to possess by our experiment: or 4/15, or between $\frac{1}{3}$ and $\frac{1}{4}$ of the whole magnitude will be metal; and consequently, 20/31 or nearly $\frac{2}{3}$ of the diameter of the earth, is the central or metalline part."

He closes his paper with the hope that the experiment may be repeated in other parts with improvements "both in the mode of computation and in the survey."

To-day we smile when we see Hutton patting Sir Isaac Newton, "this wonderful man," on the back for his surmises, that they were so near the actual fact, that the mean density of the earth is $4\frac{1}{2}$. As we now know, Newton's surmises are far nearer the truth than Hutton's result from observation.

As the original paper on this classic work is probably accessible to very few, it is believed that this epitome of it may be interesting to our readers. It is not intended to criticise the work, rather we must admire the bold effort and scientifically sound method undertaken to tackle the important question of

mean density of the earth. Inherent difficulties, however, rendered the method impracticable and the results unreliable.

In scientific investigations it is very desirable that the structure in building be composed of parts of equal strength. This was far from being the case in Hutton's work, where great disparity existed, and we see the result.

In referring to the operations at Schehallien Laplace describes Hutton as: "—— geomètre illustre, auquel les Sciences mathématiques sont redevables d'ailleurs d'un grand nombre de recherches importantes."

The accompanying reproduction map of Hutton speaks for itself.

DOMINION OBSERVATORY,
OTTAWA, CANADA.
February, 1915.

SUMMER CONSTELLATIONS

By J. R. Collins

WE are familiar with the fact that when we look out upon the friendly stars, our horizon is always a circle of which our observation point is the centre; and that as we move from place to place on the earth's surface, this circle moves with us including within its boundary a complete half of the whole star sphere.

If we stand on the pole of the earth, our horizon corresponds with the equator. When we stand on the equator, our horizon then cuts through the poles. When we stand midway between the pole and the equator our horizon circle extends 45° beyond the equator and also 45° beyond the pole. The pole and the equator are always 90° apart, so that a line drawn from the pole star to the observer and then to the celestial equator forms a right angle.

We note that in the rotation of the star sphere the stars reach the western horizon a little earlier each day. The daily increase of westward displacement by 4 minutes gradually brings the whole circle of the heavens in orderly review before us once a year at any given time of night.

The star maps contained in our annual Handbook enables one to accurately locate a celestial object and find its position in right ascension and declination. But to the amateur unfamiliar with the maps, the accompanying chart which was drawn by Dr. Reynold K. Young, of the Dominion Observatory, Ottawa, is perhaps best suited, as it gives a view of the heavens above our horizon just as it appears at the times stated.

During the summer months the constellations situated on the ecliptic: Gemini, Cancer, Leo, Virgo, Libra, Scorpio and Sagittarius in succession pass before us in the order named.

The bright star Regulus in the handle of a figure resembling

THE SKY FOR JUNE 1, 10.30 P.M.:
JUNE 15, 9.30 P.M.:
JULY 1, 8.30 P.M.

a sickle or ancient reaping hook, marks the constellation Leo, underneath and south of "The Dipper" in Ursa Major.

Spica the chief star in Virgo is directly below Arcturus, the brightest star in Boötes.

After passing to the east through Libra, the bright star

Antares in the heart of Scorpio appears. Still further to the east may be seen Sagittarius on the borders of the Milky Way, recognizable by the figure of a small short-handled dipper, the handle towards the west and the bottom towards the north.

Hercules, with its beautiful cluster, is shown midway between Sagittarius and the pole, west of Boötes and east of Lyra marked by the bright star Vega. West of Lyra the Northern Cross in Cygnus appears, whilst to the north Draco curves from a point above Ursa Major below the pole to a loop near Cepheus with his head drooping towards Hercules. The pole or central point of the ecliptic is located in the loop of Draco near the head. Many of the interesting objects for study, to be found in these regions will be found described in the HANDBOOK for 1915.

At one time in the world's history, Leo was held in much higher esteem than he commands now. At that time the summer solstice occurred when the sun was within his boundaries, but owing to the slow movement of the earth's poles this point is passed a month before the sun enters Leo. The figure of a lion's head was usual on the gates opening the irrigating canals of the Valley of the Nile. In modern times we find fountains springing from the gaping jaws of lions; a decorative symbol employed throughout the Greco-Roman world because of the belief that Leo controlled the season when the sun was within his boundaries.

The banner of ancient Persia bore the figure of the sun in Leo, and a lion with the sun at his back was sculptured on many of their palaces. The Peruvians represented Leo as a mountain lion springing on his prey. As the seasons differ by six months in the south from that of the north, the retention of Leo in his place among the stars is evidently a survival of traditions handed on from century to century, which once blazoned on the skies of the north perish not from the minds of men scattered though they be to the four-quarters of the globe. What is true of Leo is also true of many of the other constellations in this respect.

To the west of Arcturus and just under Cor Caroli, beneath the handle of the Dipper, is a faint streamy loose cluster of faint

stars, Coma Berenices, whose history is suggestive of the origin of many of the constellation names. Berenice, a beautiful queen of ancient Egypt, is said to have possessed such magnificent tresses of hair that she was the wonder and pride of the royal court. When the king, Ptolemy Soter, was about to embark on a doubtful expedition against the Assyrians, Berenice publicly vowed her tresses to the goddess of beauty in return for the safety of the king. When the king returned, the queen, true to her vow, was shorn and her tresses were placed on the altar of Venus. Shortly thereafter they disappeared from the temple and could not be found. The king expressed anger and resentment at such a sacrilegious theft but the Royal Astronomer rose to the occasion, and probably saved his head as well as the heads of the other attendants at the temple, by proclaiming that, before Venus had time to appropriate the beautiful head adornment, he had observed Jupiter in admiration to descend and snatch the tresses from off the altar and fling them against the sky so that they might be admired by all mankind, close to Arcturus' flaming fire. The king, reluctant to accept this flattering explanation, sent for the astronomer and his star maps and as these stars were not included in any of the figures of that day, the explanation was acknowledged to be quite satisfactory, and so the name ever remained.

On the morning of May 17, Delavan of the La Plata Observatory, Argentina, discovered a comet, visible in a small telescope. Its positions on that day and three days later are as follows :—

Date	R.A.	Decl.	Station
	h m s	° ′ ″	
May 16·8696	0 33 01·0	− 2 05 31	La Plata
May 19·8843	0 42 13·2	− 1 29 24	Cordoba

It was soon announced by Strömgren, of Copenhagen, Denmark, that this was a return of Tempel's periodic comet (period 5·279 years). By reference to Map II. given in the HANDBOOK it will be seen that the comet is in Cetus, near its northern boundary. Cetus does not rise above the south-eastern horizon at this time, until about 3 o'clock in the morning.

MEETINGS OF THE SOCIETY

At Toronto

February 9, 1915, — A regular meeting of the Society was held this evening, Mr. J. A Paterson, K.C., in the chair.

The decease of Mrs. J. J. Wadsworth, late of Simcoe, Ont., a former member of the Society, was reported by Mr. J. R. Collins, and Miss E. Falls then spoke appreciatingly of the kindness and helpfulness of Mrs. Wadsworth. Moved by Miss Falls, seconded by Dr. C. A. Chant, that a message of sympathy be sent to her son by the Secretary. Carried.

The paper for the evening was given by Dr. Chant on the "Aurora Borealis." The subject was treated under the following heads, — form, distribution, periodic nature, frequency, height, audibility and causes; and was profusely illustrated by lantern slides.

Moved by Mr. A. F. Hunter, seconded by Dr. A. D. Watson that a very hearty vote of thanks be tendered to Dr. Chant for his interesting and instructive address on the Aurora. Carried.

February 23, — A regular meeting of the Society was held this evening, Vice-President, Dr. A. D. Watson, in the chair. The following were elected members of the Society :—

George S. Campbell, B.A., Ingersoll, Ont.

Miss Grace Kines, Brantford, Ont.

George A. Luno, 39 Ellis Ave., Swansea, Ont.

R. S. Sheppard, B.A., 8405, 101st. St., South Edmonton, Alta.

Eric E. Wells, 74 King St. E., Toronto.

The lecture for the evening was given by Professor A. T. DeLury on "The Distances and Masses of the Planets." In a very interesting and instructive address, by means of graphical methods, he showed the way in which the distances and masses of the planets are obtained ; using as a basis, known conceptions of distance and mass on the earth.

March 9, — A regular meeting of the Society was held this evening Dr. C. A. Chant in the chair.

Reports of observations made on the sun and the appearance of numerous sun-spots were given, and a discussion followed on the relation of sun-spots to terrestrial phenomena.

The paper for the evening was given by Mr. F. L. Blake, owing to illness of Mr. R. F. Stupart. He gave a very interesting talk on the observations which he had made on the sun, with reference particularly to sun-spots.

March 23, — A regular meeting of the Society was held in the Rooms, 198 College St., this evening, Professor Chant in the chair.

The Rev. Clarence E. Woodman, Ph.D., Sc.D., LL.D., etc., of Berkeley, California, was elected a member of the Society.

Predictions for the next two weeks as contained in the HANDBOOK were referred to by Professor Chant, who also described a brilliant fire-ball he had seen on the night of Thursday, March 12th. Under "Notes and Queries," the fact that no full moon occurred in February of this year was referred to, and the query was made as to whether it was true as stated in a number of publications that such an omission had not been observed for a century and was not likely to occur again for a long period of time. Professor Chant stated that the statement was erroneous.

The paper for the evening was by Mr. R. F. Stupart, the

Director of the Meteorological Service of the Dominion, on "Solar Radiation and Weather Types." Mr. Stupart traced the progress of the work that had been done by Abbot and others to detect a variation in the amount of the Solar Radiation received by the earth. And whilst the amount of such variation is apparently small, he thought it sufficient to account for some variation of terrestrial weather types, but sufficient data had not yet been secured to warrant general conclusions as to any marked or precise effect on the weather except in so far as such variations might affect the distribution of terrestrial equatorial atmospheric currents. The lecture was illustrated by a number of charts and slides showing the distribution of atmospheric currents and their variation during the different seasons of the year. The reading of the paper was followed by a general discussion participated in, amongst others, by Professor A. P. Coleman, who queried as to the possibility of variation of terrestrial temperature being due to differing temperatures of different parts of space through which the solar system may pass.

April 6, — The regular meeting of the Society was held in the Rooms of the Society this evening. The President, Dr. J. S. Plaskett in the chair.

A plate of Saturn taken by Dr. Percival Lowell and presented to the Society with his compliments, was exhibited on the screen. The question of the planet emitting light and so interfering with the shadow of the sun's light was propounded and an interesting discussion followed. Under "Notes and Queries" several questions were received in reference to Mr. Stupart's lecture of last meeting, and answers were given by Dr. Chant.

The paper for the evening was given by Dr. L. Gilchrist on "Recent Developments in Spectroscopy." Developments in the past few years were taken up in the lecture; the manner of obtaining a spectrum was first explained, prisms or gratings being used. The difficulty of making gratings was illustrated and reference made to Michelson's new engine ruling a 10-inch plane

15,000 lines to the inch. The method of measurement of the wave-length of light was indicated. The composition of X-rays as determined by spectroscopy in the last few years was explained, and the measurement of their wave-length was stated to give from 1/1,000 to 1/10,000 of that of light.

The President expressed the thanks of the meeting to Dr. Gilchrist for his able and lucid address on the subject of Spectroscopy.

April 20, — The regular meeting of the Society was held in the rooms of the Society, this evening, Dr. C. A. Chant in the chair.

Rev. C. V. Pilcher, St. James Cathedral, was elected a member of the Society.

Under reports of observations, Mr. F. L. Blake exhibited some lantern slides of the sun showing the recent large group of sun-spots which were visible during the latter part of March.

The paper for the evening was given by Mr. W. E. W. Jackson on "Magnetic Measurements on Sea and Land."

W. E. W. Jackson, *Rec.-Sec.*

At Ottawa

January 22, 1915, — The first meeting of the Spring Term was held this afternoon at 3 o'clock, in the Geodetic Survey Building, Mr. F. A. McDiarmid presiding.

Mr. D. G. Whittle and Mr. W. S. McClenahan, proposed at the last meeting, were elected members of the Society.

Mr. A. Steadworthy was then called on to give his address on "Photography." He first outlined the development of the science from the earliest observations of the action of light on chemicals, up to the present. The contributions of Nièpce, Daguerre, Fox Talbot, J. B. Reid, Sir John Herschel, Blanco Evrard and R. J. Bingham during the early years of photography were noted specially. The introduction of the dry plate, the invention of the roll film, radiography and moving pictures also received mention. Then followed a description of the methods

now employed, especially the precautions necessary to secure the best results. Slides were used to illustrate the retouching of portraits, the use of filters, the making of "fake" pictures and variation in development and exposure.

There was discussion of several points in the lecture and a hearty vote of thanks was tendered the lecturer.

February 5, — The second meeting of the Term was held this evening in the Carnegie Public Library, Mr. J. J. McArthur presiding.

Mr. F. A. McDiarmid gave his Presidential Address on "The Evolution of Astronomy." Mr. McDiarmid traced the growth of Astronomy from the time of the earliest records of the Chinese, Indians, Egyptians, Chaldeans and Greeks; and the various "cycles" and "systems" proposed by the latter were given in detail. The advances due to Ptolemy, Copernicus, Tycho Brahe, Kepler, Galileo and Newton were described specially. Following the lines laid down by Newton, Euler, Clairaut, d'Alembert, Laplace and Lagrange developed mathematical astronomy to a very high degree. The establishment of Greenwich Observatory and the works of the Astronomers Royal, Flamsteed, Halley, Bradley and of William Herschel were next described. The parts played by Adams and LeVerrier in the discovery of Neptune was outlined in closing the lecture. Then followed a series of lantern slides illustrating the lecture from beginning to end.

February 19 — The third meeting of the Term was held this afternoon in the Geodetic Survey Building, Mr. F. A. McDiarmid presiding.

Mr. Ernest W. Jackson, was elected a member of the Society.

Mr. Noel J. Oglivie gave a paper on "Triangulation along the British Columbia Coast." This paper dealt with the Alaska-British Columbia Survey and also gave an outline of a proposed Geodetic Survey along the British Columbia Coast. All triangles

in the Primary Survey closed within one second, but one, which closed within two seconds. Fog interfered with observations on low-lying points. Slides were shown of various phases of the Survey. On the map it was shown where a glacier had retreated steadily northward 20 miles between the years 1879-1912. A chart was shown of a proposed scheme of triangulation from the north survey to connect with Mr. McCallum's Survey in British Columbia.

Mr. George H. McCallum was then called on for his paper on "The Geodetic Survey in British Columbia North from the Forty-ninth Parallel." This paper dealt with some general points in connection with such surveys, especially with the importance of reconnaissance, the preparation of a station, the clearing of lines and the fixing of points. Of the 28 points of Stitt's reconnaissance in 1910, 24 were used in this survey. The Survey triangulation was connected to the two points, Iceberg and Discovery, in the U. S. Coast and Geodetic Survey. A map showed the network of the triangulation, including the base line below Vancouver. Slides were used to illustrate the lecture.

March 5, — The fourth meeting of the Spring Term was held this evening at 8 o'clock, in the Carnegie Public Library, Mr. F. A. McDiarmid presiding.

Professor Bernard Gavin, of Ottawa University, gave a lecture on "The Principles of the Telescope." Professor Gavin explained how light was refracted, using experiments with plate glass and prisms in illustration. He showed how the prism deviated the path of a beam of a light ; and from this step explained how a convex lens brought the rays of light to focus on an axis, the different colors at different distances from the lens. Then he showed how by using a concave lens of another glass the various colors could be brought to nearly the same focus.

The lecturer had a 6-inch equatorial telescope to explain how any star could be observed by pointing the telescope in

accordance with readings on the declination and right ascension graduated circles. The various accessories of a modern telescope were then mentioned and their uses briefly outlined.

March 19, — The fifth meeting of the Term was held this afternoon at 3 o'clock in the Geodetic Survey Building, Mr. F. A. McDiarmid presiding.

Mr. R. M. Stewart was then called on to give his part of a lecture on "Wireless Telegraphy in Longitude Determinations." Mr. Stewart outlined the principles involved in the determinations of longitude, and showed how it could be determined relatively for two stations if the times of transit of a star were observed at the two stations, provided the clocks were known in terms of one another. Thus longitude could be determined by moving a constant rate clock from one station to another, by flashing lights from one station to another, by transmitting the time by wire or by wireless — any method which would serve to relate the time-measuring apparatus in the two stations. The last method was used for the Observatory and several stations in Quebec by comparing the clocks at these two stations with one another through comparisons with the time sent out by Arlington, though any arbitrary rhythmic wireless beats could serve. The clocks at the Observatory and at the station were rated to gain about 10 minutes a day or 1 second in $2^m\ 24^s$, and therefore having two coincidences during the 5 minutes before 10 o'clock each night when Arlington beats out the seconds by wireless. The Observatory clock was also rated by chronograph with a sidereal clock before and after the observations so both observing clocks would be known exactly in terms of one another. Tables of measures for four stations in Quebec showed good agreements:

Quinze Dam	Jct. of the Kinojevis with the Ottawa R.	H. B. Post Grand Lake Victoria	Lake Barriere
7 Nights	6 Nights	4 Nights	3 Nights
m s	m s	m s	m s
14 00·97	11 46·85	0 56·46	3 56·58
7·00	·94	·50	·24
7·06	·68	·34	·42
6·92	·66	·27	
6·97	·77		
7·00	·96		
7·14			
14 7·025	11 46·80	0 56·39	3 56·38

Results indicate that in the future measures could be made as accurately as by wire.

Mr. W. A. Dier was then asked to give his part of the lecture. Mr. Dier described the trip into the wilds of Quebec, the difficulties experienced, the method of choosing sites and of erecting the receiving wires and many interesting adventures along the way. A series of lantern slides, illustrated his remarks. Mr. Dier told of some of the interesting messages he picked up by wireless. One of these, from Washington to a ship far out at sea, was: "Read Psalm 143, verse 6, — Edith" which Mr. Dier translated: "I stretch forth my hands unto thee: my soul thirsteth after thee, as a thirsty land." Mr. Dier was able to supply the war news daily in places which would ordinarily have to wait a week for the newspapers. Several messages of importance to the Militia Department were also picked up.

March 26, — The sixth meeting of the Term was held this evening in the Carnegie Public Library, Mr. F. A. McDiarmid presiding.

Professor Chant was then introduced and called on to give his lecture on the "Aurora." Dr. Chant showed a magnificent series of slides from drawings and photographs made by several expeditions and explorers in the north. The colors were shown and the various forms of auroras depicted. The more recent

photographs taken simultaneously by Störmer and Birkeland at two points along a meridian separated by accurately known distances of 4·3 and 27·5 kilometres, showed the aurora projected differently on the star-sphere. These photographs served for measuring the heights of auroræ, which were found to vary from 45 to 325 kilometres.

The periodicities of the aurora were shown by curves; the 11-year period agreeing with the sun-spot and terrestrial magnetic curves, the daily period resembling the daily magnetic change, and a yearly period showing maxima about February and August.

The explanation of the cause of the aurora favored by Dr. Chant was that varying streams of electrons are projected from the sun, which striking the earth produce discharges in the upper atmosphere.

The question of the audibility of the aurora was discussed; from the evidence to date we must conclude that the aurora sometimes makes a crackling sound like that produced by a frictional electrical machine.

In addition to the scientific presentation of the subject, the beautiful descriptive poetry of R. W. Service and Dr. A. D. Watson was read.

Dr. Klotz and Mr. R. M. Stewart proposed a vote of thanks to the lecturer, which was heartily endorsed by all.

R. E. DeLury, *Sec.*

REVIEW OF PUBLICATION

Stellar Movements and the Structure of the Universe. By A. S. EDDINGTON.

The number of researches undertaken and the number of valuable papers published in the last decade on the motions of the stars and general theories of cosmogony attest the progress of our knowledge concerning the structure of the universe. So rapid has this progress been and so diverse have been the lines of attack, that it is difficult even for a worker in this field to correlate the results of the many investigations. Any book, therefore, which summarizes the present status of the problem is particularly valuable, not only to the general reader, but also to the professional astronomer.

Two years ago appeared a book entitled "Stellar Motions," by W. W. Campbell. This book summarized the results of his own and other investigations, special attention being given to the results from radial velocity. The recent book by A. S. Eddington, entitled "Stellar Movements and the Structure of the Universe,"* not only presents the status of our knowledge down to a very recent date but brings out particularly the results obtained from the study of proper motions, star-counts and statistical investigations in general.

The first chapter of the book is devoted to a discussion of the data upon which the study of the universe is based. Ideally, the proper motions, magnitudes, types of spectra,

* Macmillan Science Monographs. Pp. XII + 266. London: Macmillan and Co., Limited, 1914. Price, 6s Net.

radial velocities and parallaxes should be known. For only a very few stars, are all five of these quantities available. The data for proper motions is fairly complete down to magnitude 6·5; a certain amount is available down to magnitude 13, but it is fragmentary. Lapse of time will devolop our knowledge of proper motions satisfactorily. Apparent magnitudes, according to a standard scale, are fairly complete down to magnitude 6·5 and in restricted areas down to about 17. The data, however, is complicated by the fact that there are two sets of magnitudes, visual and photographic. Absolute magnitudes are known for very few stars because an accurate determination of the distance is prerequisite. Spectral types according to the Draper classification are complete to magnitude 6·5 and are being extended rapidly. Radial velocities are available for about 1500 stars, including all those with measurable lines that have a visual magnitude brighter than 5·0. The parallax data is the least extensive of all. Fairly accurate parallaxes have been determined for about 50 stars. The bibliography given at the end of this chapter and, indeed, at the end of every chapter will be found very useful as a guide to the literature of the subject.

Chapter two, consists of a brief summary of the results which have been deduced from the data. The methods by which they are obtained and the separate investigations are treated in more detail in the subsequent chapters. The genera summary preceding the work enables the reader as he proceeds to relate the different points brought out to the conception of the universe as it is believed to be.

The nearest stars are first considered. For these practically the complete data are at hand and while the number of stars is very small some very interesting conclusions are drawn. The density of the stars near our sun is about thirty to a sphere 5 parsecs* in radius. The luminosity of the stars decreases from

* A *parsec* is the distance which corresponds to a parallax of one second of arc or 3·26 light-years.

the *B* to *M* type. It is further shown that these stars have abnormally high velocities.

In the next chapter, the phenomena of moving clusters is discussed. The Taurus, Ursa Major, Perseus clusters are considered in turn and the important conclusion is drawn that a group of stars, the individual members of which are situated at vast istance from each other, may move through the universe intact, the individual motions remaining nearly parallel. The path of a star is in general little affected by the chance attractions of those stars near which it may pass.

Investigations relating to the sun's motion and the motions of the stars are found in chapters five, six and seven. Two solutions of the sun's motion in recent years have superseded all others, one depending on proper motions and the other on radial velocities. The proper motion solution carried through by Boss from over six thousand stars gives as the apex of the sun's way.

$$\alpha = 270°{\cdot}5 \pm 1°{\cdot}5,$$
$$\delta = +34°{\cdot}3 \pm 1°{\cdot}3.$$

The radial velocity solution by Campbell from over 1000 stars gives

$$\alpha = 268°{\cdot}5 \pm 2°{\cdot}0,$$
$$\delta = +25°{\cdot}3 \pm 1°{\cdot}8.$$

Speed of solar motion $19{\cdot}5 \pm 0{\cdot}6$ km. per second.

The discrepancy between the declinations seems to be real. There is some evidence, however, that the declinations obtained for the solar apex depends on the magnitudes of the stars employed in the solution, the fainter the stars the farther north the apex. The magnitudes used in the proper motion solution extend a magnitude and a half fainter than those for which we have radial velocity.

The fact that the great bulk of the stars may be divided into two classes, those in one of which are moving toward a point in R. A. 93°, Decl. + 12°, and the other 180° from this, is very strikingly shown. The two star streams seem to be at about the same average distance from the sun and to be very

well mixed in all parts of the sky. That stream moving toward the point in R. A. 93°, Decl. + 12° contains the larger percentage of the stars. The velocity of approach of the two streams is about 40 kilometres per second. There is also strong evidence that we should class some of these stars and all *B* type stars by themselves in a third drift which is at rest with respect to the universe or in relation to the sun in moving toward R. A. 90°, Decl. − 34°.

The mathematical discussion upon which the solutions are based is taken up in chapter seven. The average reader will find this chapter rather difficult to handle as the treatment is condensed. The segregation of the mathematics of this part of the work into one chapter has a distinct advantage. It enables the general reader to skip at one jump all that does not interest him, without feeling that he is missing an integral part of the book and it enables those who follow the mathematics closely to find a ready reference to the different treatment of the subject.

Chapter eight contains an interesting discussion of the phenomena connected with spectral type, though the results seem to lead to puzzling contradictions. The first point brought out is that the speed and type are related, early types moving slowly and later types more rapidly. This would indicate that the order of evolution of the stars corresponds with the Draper classification. The data from spectroscopic binary orbits, that the mean period of revolution lengthens with the advance in type, are usually taken to confirm this order. The degree of galactic concentration shown by the different types is also significant. The determinations of the mean distance of the different spectral types both from the proper motions and the radial velocities show that the *B* and *M* types are farthest removed, the *A* and *K* next in order and *F* and *A* the closest. Now if the *M* types are far removed, a majority of those that enter our catalogues must be very luminous. In chapter three it was mentioned that the *M* types were found to be the least luminous of all. The theory of dwarf and giant stars overcomes this apparent discrepency. According to this theory the later types are made up

of two classes, those highly luminous and those much fainter. The parallax data of chapter three included the proximate *M* type stars, these being faint; the statistical investigation down to a given magnitude contains the giants of these classes. The theory suggests, however, that the complete order of evolution is *M*, *K*, *G*, *F*, *B*, *A*, *F*, *G*, *K*, *M*, the luminous and faint stars of *M* type being found at the two ends of the scale. In statistical investigations the faint *K* and *M* types will not be numerous enough to effect our result, and dropping the bright *G* and *F* types, since the measures of distance show that this class is the closest, we would write as the most probable scale of evolution as it should be shown by statistical investigation, *M*, *K*, *B*, *A*, *F*, *G*, which is contrary to the confirmed order *B*, *A*, *F*, *G*, *K*, *M*.

The results given in the next two chapters on star-counts and statistical investigations rest on the assumption that the absorption of light in space is negligible. If the future should show that this must be taken into account, our ideas on the structure of the universe would be considerably altered. In the counts of stars, greatest weight is given to an investigation by S. Chapman and P. S. Melotte. Their results fix the number of stars in the universe between one and two billion with a median magnitude of twenty-three.

The statistical investigations have as their aim the determination of *the density law*, the number of stars per unit volume of space in different parts of the system; *the luminosity law*, the proportion of stars between different limits of absolute brightness; *the velocity law*, the proportion of stars having linear velocities between different limits both of amount and direction. While the results show some discordances, a very important point as Eddington remarks is that the different lines of attack outlined in the chapter lead to two independent methods which serve to check the accuracy of both. Our knowledge of the Milky Way, of the vast numbers of stars, which compose it, of their magnitudes, numbers, spectra, is still lacking. In the discussion of clusters and nebulæ. The theory that the spiral nebulæ are island universes, probably similar to our own, is

favored. This theory leads to a working hypothesis for the investigation of our own system.

In the last chapter of the book the author presents the little that is known concerning the dynamics of a stellar system. The existence of the moving clusters shows that the interaction of the stars on their neighbors must be very small. The general gravitational effect of the universe is much larger. An attempt is made to account for the velocities of the stars on the basis of this attraction and while it seems sufficient to account for the magnitudes of the velocities, difficulties are encountered in the explanation of the relation between type and speed.

It has been impossible for the reviewer to more than touch on a few of the many interesting points given in the text. The book is crowded throughout with suggestions and hypotheses which the reader will find interest in perusing. As the author mentions in the preface, it was his aim to outline the present state of our knowledge as based upon the most recent data, and for this reason the work of the pioneers in the field whose labors laid the foundation for our progress is largely omitted.

REYNOLD K. YOUNG.

NOTES FROM THE METEOROLOGICAL SERVICE

Summary Report of the Weather in Canada

April, 1915

Temperature. — The mean temperature of April was higher than the average throughout the Dominion, except in the southern parts of the Maritime Provinces. The widest positive departure occurred in the Western Provinces, where in Saskatchewan it was 12°, and in Manitoba 10°, whence eastward it diminished to between 5° and 8° in Ontario, and to 1° in Northern New Brunswick, and to 0° or 1° negative in more southern portions of the Maritime Provinces. In British Columbia a positive departure of 7° in the Upper Mainland diminished to about 1° near the coast.

Precipitation. — The precipitation was less than average in nearly all parts of the Dominion, except New Brunswick, Central Nova Scotia and the more northern districts of Alberta and Saskatchewan. The deficiency was greatest in the West, between Swift Current and Medicine Hat, where there was neither rain nor snow, and the largest excess occurred in the Maritime Provinces between St. John and Halifax, and on the 29th rain began in the latter district and continues to date.

Temperature for April, 1915

Station	April		Station	April	
	Highest	Lowest		Highest	Lowest
Yukon			Kinmount	84	17
Dawson			Kingston	72	32
British Columbia			Lakefield		
Atlin			London	87	21
Agassiz	76	31	Lucknow	84	16
Barkerville	60	22	Madoc		
Kamloops	80	32	Midland		
New Westminster	71	36	North Gower	88	28
Prince Rupert	56	34	Otonabee		
Vancouver	66	36	Ottawa	86	26
Victoria	67	39	Owen Sound		
Western Provinces			Paris	90	24
Battleford	80	20	Parry Sound	83	11
Broadview			Peterboro'	86	24
Calgary	77	24	Port Arthur	70	16
Carman			Port Burwell	70	24
Edmonton	79	23	Port Dover	79	24
Medicine Hat	87	29	Port Stanley	81	23
Minnedosa	85	13	Ronville	83	13
Moose Jaw	88	12	Sarnia		
Oakbank	84	18	Southampton	81	23
Portage la Prairie	85	11	Stonecliffe	88	15
Prince Albert	76	14	Stony Creek	86	26
Qu'Appelle	83	15	Stratford		
Regina			Toronto	84	26
Swift Current	84	23	Uxbridge	84	22
Winnipeg	84	19	Wallaceburg	87	20
Ontario			Welland	84	24
Agincourt	85	25	White River	78	- 2
Aurora	84	20	*Quebec*		
Bancroft	85	20	Brome	77	20
Barrie	84	22	Father Point	54	12
Beatrice	82	15	Montreal	82	28
Birnam			Quebec	68	26
Bloomfield	78	25	Sherbrooke	80	20
Brantford	89	23	*Maritime Provinces*		
Bruce Mines			Charlottetown	58	20
Chatham	91	22	Chatham	60	16
Clinton	84	21	Dalhousie		
Cottam	87	15	Fredericton	64	21
Gravenhurst	84	15	Halifax	70	26
Guelph	84	20	Moncton		
Haliburton	88	13	St. John	64	24
Hamilton			St. Stephen	68	14
Huntsville	85	15	Sussex		
Kenora	62	16	Sydney	60	18
			Yarmouth	56	26

MAGNETIC OBSERVATIONS

During the month of April the magnetic elements as recorded at Agincourt indicate considerable disturbance in the Magnetic Force from the 2nd to the 9th, from the 15th to 23rd and on the 26th, the remaining days being normal.

The most pronounced disturbances were on the 7th and 8th, 18th and 19th and 26th.

The first of these was marked by a sudden commencement in all three elements at $14^h\ 45^m$ of the 7th. In D the Westerly Declination increased 7'·6 followed by a rapid diminution of 16'. In H the Force decreased 51γ and then rapidly rose 166γ and in V the Force fell 8γ followed by a rapid rise of 30γ. The storm continued fairly active in all elements, with no succeeding great changes of amplitude, until about 18 hours of the 8th.

The second large disturbance on the 18th and 19th was confined chiefly to the night hours, with no rapid changes in any element. In D the curve presents the appearance of a series of bays, the time from point to point being about an hour and the depth varying from a few minutes to about 26 minutes. The H curve is a little more serrated but deviations are small. In both D and H the curves are normal during the day. In the V curves on the night of the 17th and early morning of the 18th two large bays are recorded with a maximum decrease of 61γ each in the Force, and with a duration of about two hours each. The curve was normal again during the day of the 18th but in the evening the V Force again decreased and maintained an average of about 44γ below normal during the night. On the 19th the V force increased gradually all day reaching a maximum of 44γ above normal at 18 hours. It then became slightly subnormal during the night returning to normal on the early morning of the 20th.

The third disturbance was marked in all elements by moderately large bays and with no rapid oscillatory movements in the Force. The beginning was gradual about 21 hours of the 25th and the Force became normal again about 18 hours of the 26th.

During this disturbance the minimum values for all three elements for the month were recorded.

The table given below is an abstract of the results obtained at Agincourt during April.

	April, 1915	D. West	H	V	I
		° ′			° ′
	Mean of Month	6 28·1	0·16042	0·58660	74 43·0
	Maximum	6 49·2	0·16189	0·58725	
	Date of Maximum	18	7	22	
	Minimum	6 09·1	0·15945	0·58535	
	Date of Minimum	26	26	26	
	Monthly Range	0 40·1	0·00244	0·00190	
Mean Daily Amplitude	From hourly readings	0 11·9	0·00043	0·00016	
	From Means of Extremes	0 19·1	0·00075	0·00042	

H and V are expressed in C. G. S. Units.

I is the Mean of all Dip observations made during the month with the Earth Inductor, without regard to the time of day at which they were made. Two observations are usually made each week.

Earthquake Records by the Milne Seismograph

TORONTO

R. F. Stupart, Director.

P.T. = Preliminary Tremors. L.W. = Large Waves. A.C. = Air Currents.
Time is Greenwich Civil Mean Time, 0 or 24 h = midnight.

No.	Date 1915	P.T. Comm.	L.W. Comm.	Max.	End	Max. Amp.	Durat.	Remarks
		h m	h m	h m	h m	mm	h m	
1449	Apr. 2	6 2·5	6 12·1	6 14·5	6 19·8	0·2	0 17·3	
1450	" 3	20 49·1?	21 0·9) 21 6·7)	21 11·2	21 45 8	0·5	0 56·7	
1451	" 3	22 0·0?	22 5·4	22 6·7	22 32·6	0·1	0 32·6	
1452	" 7		16 15·5) 16 16·3)	16 16·8	16 20·8	0·3	0 5·3	
1453	" 7		16 35·8		16 43·2	0·050	7·4	
1454	" 8		14 44·2	?	14 51·9	0·2	0 7·7	
1455	" 23	15 38 8?	15 52·7	16 1·0	16 14·2	0·2	0 35·4	
1456	" 28	4 4·5	4 16·8	4 23·9	4 34·0	0·1	0 29·5	
1457	" 30	2 15·8?	2 39·2		3 3·4	0·050	47·6	

Period 18 seconds. Pillar deviation 1 mm. = 0″·59.

VICTORIA, B. C.

F. N. Denison, Superintendent.

No.	Date 1915	P.T. Comm.	L.W. Comm.	Max.	End	Max. Amp.	Durat.	Remarks
		h m	h m	h m	h m	mm.	h m	
1457	Apr. 2	0 18 9	0 20·4	0 20·9	0 24·9	0·2	0 6·0	
1458	" 3	20 41·9	20 46·9	20 59·9	21 26·4	0·3	0 44·5	
1459	" 3	21 42·8?	21 49·6		22 7·6	0·1	0 24·8	
1460	" 7	16 18·0?	16 20·0	16 20·3	16 23·8	0·1	0 5·8	
1461	" 8	14 37·7	14 38·7	14 41·2	14 45·7	0·4	0 8·0	
1462	" 23	15 40·1	15 48·3	15 49·1	16 08·6	0·4	0 28·5	
1463	" 26	19 00·3?		19 00·3	19 02·3	0·1	0 2·0	Doubtful as to being seismic.
1464	" 28	4 05·9	4 09·4	4 10·4	4 25·4	0·2	0 19·5	
1465	" 30	2 11·5	2 29·5	2 35·0	2 58·5	0·2	0 47·0	

Period 18 seconds. Pillar deviation 1 mm. = 0″·54

J. Y.

ASTRONOMICAL NOTES

WOLF-RAYET STARS — The stars of this group are not numerous. The northern constellation of the Swan contains a few; a few have been elsewhere detected; but the most conspicuous of them all is γ Argus. It is interesting to notice that the great variable η Argus also belongs to this class. There is a recent note on this star by Mr. R. T. A. Innes, of South Africa, who has been keeping watch over it for the last 18 years, wherein he states that its magnitude (say 7·75) has been fairly constant for the last 15 years; he has added it to the long list of his own discovered doubles, and finds highly probable evidence of its binary character. The two stars, magnitudes about 8·0 and 10·5 are exceedingly close, and the appearances suggest that the outbursts of light which have occurred in the past have been caused by periastral grazings. Its light is always described as "fuzzy." But the grazing of the stars (if so be) has given astronomy the most brilliant new star in all history. Sir John Herschel at the Cape in 1834 noted it brighter than Sirius. This, then, is one of these Wolf-Rayet stars. The latest spectrogram of the Lick Observatory shows a reversal of the dark lines.

Professor Nicholson describes these stars as "one of the earliest products of some form of evolution which has taken place in primitive nebulæ." The elements which they reveal may have no terrestrial existence; they may be the proto-elements of Lockyer. We must at present frankly regard their spectrum as almost entirely of unknown origin. Hydrogen and helium are certainly recognisable, but these seem all. The novæ, and in particular the celebrated Nova Aurigæ, seem to

possess a Wolf-Rayet stage, and the investigation "points strongly to the conclusion" (I am quoting Professor Nicholson) "that the Wolf-Rayet stars are a very early evolution product of the nebulæ, for they link up the spectra very completely with at least a part of the nebular spectrum."

But more than this, the Wolf-Rayet stars indicate not only a link of a celestial order on the vast scale of the stellar universe, between one great segment of heavenly bodies and another—between nebulæ and stars; but they possess an almost equal interest for the physicist in the world of the infinitesimal, as an *aperçu* into an interpretation of the atom. When I tell you that Professor Nicholson's researches on these Wolf-Rayet stars and on the element nebulium take us into a region where we are invited to judge of identifications among wave lengths wherein the French metre is divided into 10^{10}—ten raised to the tenth power, the 10,000-millionth of a metre, or the 10-millionth of what microscopists call a millimetre—you will see how vast is the range of the science of physical astronomy.

We find ourselves, in fact, adventuring into a primeval region, *claustra portarum naturæ effringentes*, in a sense far beyond the dreams of Lucretius. Professor Nicholson has to go back behind hydrogen and helium to nebulium—the characteristic spectrum of the nebulæ.

Nebulium, *e.g.*, is not a form of hydrogen or helium, but a new element lying between them in Mendelćeff's table—its atomic weight being probably nearly three. The general conclusion must be that in the nebulæ are contained the elements which can fill an upper row in the table, preceding helium. There are the atomic structures from which all the heavier elements have been derived, by an evolutionary process, which must be the exact converse to the process of radio-activity [which is a *dis*integrating process]. We can deduce, therefore, that stellar evolution proceeds by a progressive modification of the atomic nuclei. We are thus thrust back to various "simple ring systems, with simple nuclei," simpler than any discussed by Professor Rutherford in the recent visit of the British Associa-

tion; and finally to a nebular line λ 3729 which Professor Nicholson ventures to name the nucleus of the primordial proto-element — Arctonium. With it goes the extraordinary result that the Orion nebula may have a temperature vastly exceeding that of our sun — a temperature of 15,000° C.

"The physical state of the nebula, moreover, must be analogous to that of a very exhausted vacuum tube of enormous extent."

Such is the strange "fiery cloud" (as we were first accustomed to call it) on which these researches have been bestowed. Such the attenuated beginnings of material substance; yet verified by spectrum identifications which are exact to magnitudes measured in millionths of a millimetre.

There I shall leave it, but the subject is so stupendous and so fascinating that I promise myself the pleasure of returning to it on some future occasion. — PRESIDENTIAL ADDRESS, New South Wales Branch, *B. A. A. Journal*, February, 1915.

HARVARD College Observatory, *Bulletin*, No. 580, states that Professor E. E. Barnard, of the Yerkes Observatory, has discovered two companion bodies near Mellish's Comet. One of these was conspicuous, and had a distance of 28″ and a position angle of 285°, on May 12, at 19ʰ 36ᵐ. The other was faint, and occupied an intermediate position in the same line.

ON the presentation of the Gold Medal of the Royal Astronomical Society to Professor Fowler for last year the President stated:—"So complete is this accord in process of becoming that we are now witnessing the strange development that not only does the astronomer appeal to the physicist to help him in his difficulties and interpret physical observations made on distant bodies—this appeal is a natural one and excites no astonishment, —but what appears at first sight unnatural is that the converse appeal is now being made and the physicist is asking the astronomer's help. We may well rub our eyes when we see the attempt to derive knowledge of the internal constitution of the atom from observations of the solar corona or nebulæ; but such attempts are made, and our Medallist's work has no small bearing upon them." —*Monthly Notices* R. A. S., No. 4. J. R. C.

NOTES AND QUERIES

Communications are Invited, Especially from Amateurs. The Editor will try to Secure Answers to Queries.

QUERY

Is it true that Copernicus never saw Mercury?—Question at a Toronto meeting of the Society.

ANSWER

It is not easy to give a satisfactory answer to this query. It seems to be the general belief that Copernicus did not see Mercury.

Proctor in *Half-Hours with the Telescope*, p 77, says:—

Copernicus never saw Mercury, though he often looked for him.

Newcomb in his *Popular Astronomy*, p. 289, says:—

It is said Copernicus died without ever having been able to do it.

Young in his *General Astronomy*, sec. 551, says:—

Copernicus is said never to have seen it.

Chambers in his *Handbook of Astronomy*, 4th ed., I., p. 91, says:—

It is rather difficult, in a general way, to see Mercury, and Copernicus, who died at the age of 70, complained in his last moments that, much as he had tried, he had never succeeded in detecting it; a failure due, as Gassendi supposes, to the vapors prevailing near the horizon on the banks of the Vistula where the illustrious philosopher lived.

Ball in *The Story of the Heavens*, (1901 Edition) p. 156, says:

At the close of his memorable life Copernicus was heard to express his sincere regret that he never enjoyed an opportunity of beholding the planet Mercury. He had specially longed to see this body, the movements of which were to such a

marked extent illustrative of the theory of the celestial motions which it was his immortal glory to have established, but he had never been successful.

On the other hand, Berry, in his *Short History of Astronomy*, p. 96 says :—

Copernicus, moreover, points out in more than one place that the high latitude of Frauenburg and the thickness of the air were so detrimental to good observation that, for example, though he occasionally had been able to see the planet Mercury, he had never been able to observe it properly.

In an effort to get first-hand information I examined Copernicus's great work *De Revolutionibus Orbium Cœlestium*, and the only reference that I could find is in chapter 30 of book V. (p. 387, Thorn edition, 1873). The chapter is headed "Concerning more recent observed motions of Mercury" and the first portion is as follows :—

Hanc sane viam huius stellæ cursum examinandi prisci nobis præmonstrarunt, sed cælo adiuti sereniori, nempe ubi Nilus (ut ferunt) non spirat auras, quales apud nos Vissula. Nobis enim rigentiorem plagam inhabitantibus illam commoditatem natura negavit, ubi tranquillitas aeris rarior, ac insuper ob magnam sphæræ obliquitatem rarius sinit videri Mercurium, quamvis in maxima solis distantia, siquidem in Ariete et Piscibus non oritur conspectui nostro, nec rursus occidit in Virgine et Libra, sed neque in Cancro se repræsentat vel Geminis quoquo modo, quando crepusculum noctis solum vel diliculum est, nox vero numquam, nisi sol in bonam partem Leonis recesserit. Multis propterea ambagibus et labore nos torsit hoc sydus, ut eius errores scrutaremur. Mutuavimus propterea tria loca ex eis, quæ Nurimbergæ sunt diligenter observata.

With the assistance of a colleague, I translate this as follows :—

To be sure the ancients showed us this method of investigating the path of this star, but they were fortunate in having a clearer atmosphere to work in [literally, were aided by a clearer sky], namely, the country of the Nile, which gives off no vapors [lit., breezes] like our Vistula. Nature has given us a sterner climate, and denied us their advantage ; here a calm air is experienced less often ; besides, on account of the great obliquity of the sphere [due to high latitude], Mercury can be seen less often, even when at greatest elongation from the sun, for in Aries and Pisces it does not rise so that we can see it, nor again

does it set in Virgo and Libra, nor does it show itself at all in Cancer, except in the evening twilight or early morning, unless when the sun has gone far into Leo, — under no circumstances at night. And so this star has, in our endeavor to investigate *its* wanderings involved *us* in a very dubious way, and occasioned us much toil. That is why we borrowed three of the observations made so carefully at Nuremberg.

From this I would understand that Copernicus was aware that Mercury could be seen as an evening star when the sun was in Aries or Pisces, and as a morning star when the sun was in Virgo and Libra ; but there is no intimation that *he* had seen it. I feel sure this subject must have received a full discussion during the past centuries ; and if this should meet the eye of anyone who has looked into the matter more fully, I should like to hear from him.

THE DRAPER MEMORIAL

For a considerable number of years a great work has been in progress at the Harvard College Observatory under the name of "The Draper Memorial;" and readers of the JOURNAL are favored in having in this issue a concise and lucid account of it, written by one who has had much to do with the successful carrying out of the great project. Mrs. Draper died on December 8, 1914, and in her will she left $150,000 wherewith to continue the work. If all the astronomers of the world had been consulted I believe they would have agreed that this sum of money could not be better spent for the general advantage of astronomy.

BLACK LIGHTNING

In last month's JOURNAL was an interesting article on "Black Lightning," illustrated by two striking photographs of this odd phenomenon. On the evening of Sunday, April 25, a heavy electrical storm passed over the northern part of Toronto and Mr. Wm. James, 250 Major St., Toronto, secured from his attic

window a negative on which the ramifications of an apparently dark flash are seen.

In *Nature*, Vol. 60, 1899, are several letters and articles dealing with this subject. The longest of these is by Dr. W. J. S. Lockyer, and it shows pretty conclusively that the dark flash has not an objective reality but that it is due to chemical action in the photographic plate.

If, after the plate has been exposed to a flash, the camera is left open, so that light from a second flash, or from a faint source acting for some time, be allowed to fall upon it, the image of the first flash may become reversed. Dr. Lockyer was able to reproduce the effect by means of an induction coil. Similar results from experiments had been given in 1889 by A. W. Clayden, and this peculiar reversal is sometimes known as the Clayden effect.

In reference to the reversed negatives taken in Algonquin Park, referred to by Mr. Steadworthy, perhaps they might have been due to faint light entering the camera after the exposure had been made.

THE OBLATENESS OF URANUS

Whether or not one agrees with all the conclusions which Dr. Percival Lowell draws regarding conditions existing on the surface of Mars, there will be no denial of the statement that since he established his observatory about twenty years ago and surrounded himself with a company of keen and skilful young astronomers, our knowledge of the planets has been materially increased and interest in the subject has been widened and quickened.

On account of the great distance of Uranus from us, namely, about 1800 millions of miles, our knowledge of it is somewhat meagre. For many years its rotation period was unknown, analogy to Jupiter and Saturn leading to the suspicion that it was short. About three years ago, by means of the Lowell

spectrograph, the period was shown to be about 10¾ hours, thus verifying our suspicions.

In the latest *Bulletin* from the Lowell Observatory, No. 67, there is further information regarding Uranus. The flattening at the poles of Jupiter and Saturn is so decided that a small telescope will reveal it, but in the case of Uranus the disc is very small and the axis of the planet is tilted from us at a considerable angle. The equatorial diameter was measured directly and from measurements of the *apparent* polar diameter the *true* polar diameter was calculated. The results were :—

Equatorial diameter 36″·166,
Polar diameter 33″·009,

from which the flattening is 1/11·55. In Young's *Manual of Astronomy* the flattening of other planets is given as follows :—

Earth, 1/300 ; Jupiter, 1/16 ; Saturn, 1/10.

Further, it is evident that the amount of the flattening depends on the density of the planet, its speed of rotation, its size and the way the matter is distributed through it ; but if, conversely, we attempt to calculate the distribution of the matter, being given a knowledge of the flattening, density, speed and size, we obtain a problem too complex to solve in general terms. But some approximation can be made to the distribution in special cases. Lowell calculates the flattening which Uranus should exhibit on two hypotheses : (1) that the planet is homogeneous throughout, (2) that its matter is condensed at the centre ; and he finds the result obtained under the first supposition much nearer the observed value than that under the second supposition. This result is the reverse of that obtained for Jupiter and Saturn, and leads to the view that for Uranus the line of evolution was different from that for the other two planets.

The concluding paragraph of the *Bulletin* is as follows :—

From these figures an interesting result emerges, to wit : that the matter composing Uranus is more nearly in a state of homogeneity than that of either Jupiter or Saturn ; very markedly so. This fact has something to say about the method

of evolution of our Solar System, for proceeding outward from the sun we find the terrestrial planets with a mean density of 3·5 to 5·5 that of water and a law of density distribution nearer homogeneity than central concentration; Jupiter with a mean density of 1·25 that of water and a law of density distribution nearer central concentration than homogeneity; Saturn, with a mean density of ·72 that of water and approaching still nearer to central concentration; and now, finally, Uranus, with a mean density like Jupiter and yet nearer homogeneity than its opposite. This would seem to indicate a method of development in the aggregation of matter.

UNITED STATES COAST AND GEODETIC SURVEY

It is only a few years since a geodetic survey of Canada was definitely undertaken, and in a number of papers published in this JOURNAL the nature of its work and the progress being made have been described.

A pamphlet recently revised for distribution at the Panama-Pacific Exposition gives a very interesting account of the Coast and Geodetic Survey of our friends to the south. The description given of the work, methods and organization of the Survey reveals its magnitude and the nature of its numerous branches.

The Survey was authorized by Congress in 1807, but field work did not begin until 1816, and after continuing for two years, it was suspended until 1832, from which date it has regularly continued. At present the field force consists of 181 technical men, 345 enlisted men, an average of nearly 100 additional employees who are necessary to ensure the effectiveness of the field parties on shore, besides a large number of laborers hired for brief periods when needed. The office force numbers 160.

The following are the names of the chapters under which the work is described: History and organization, Triangulation, Base lines, Astronomy, Terrestrial magnetism, Topography, Hydrography, Tides and tidal currents, Coast pilots, Levelling, Nautical charts, Oceanography, Gravity, Geodesy or measurement of the earth, Archives.

These give some idea of the great range of the Survey's operations. Each subject is necessarily treated briefly, but in a

clear manner, and is well illustrated. It is impossible to discuss here any part at length, but the present writer was much pleased with the explanation given on page 53 of the terms 'isostasy', a word frequently heard but not always understood. It is as follows:—

> The theory of isostasy postulates that at and beneath a certain depth below sea-level, found by investigation to be 122 kilometres (76 miles), the earth's materials are in equilibrium as if they were fluid. Therefore, in each column of the same cross section which extends from the depth of compensation to the actual surface of the earth, whether land or water, there will be the same mass or amount of material. In other words, the materials in any column would weigh as much as the materials in any other column, if the weighing were done at the same place. It is therefore concluded that elevated regions are held up owing to the lesser density of the materials composing the column of which they form a part, and conversely the depression of the ocean bottoms is due to an excess of density.

Copies of the pamphlet may be obtained by addressing the Department of Commerce, Washington, D.C.

AUDIBILITY OF THE AURORA

Still further evidence has reached me regarding the above subject. In the *Philosophical Magazine*, for June, 1850, Capt. J. H. Lefroy, R.A., who was in charge of the Magnetic Observatory at Toronto, publishes a summary of observations on the aurora made in Canada during the previous two years; and in a second report, issued in 1852, further information was given. Mr. John W. Lethaby, of Victoria, B.C., has sent the present writer a quotation from the latter, which I give herewith.

> Mr. Hardisty, [of the Hudson's Bay Co.,] writes as follows:—"During a voyage in the beginning of the past winter, I saw the most beautiful display of the Aurora Borealis that I have ever witnessed. On the 2nd December, 1850, I was encamped on the banks of a moderate sized river near the chain of the Rocky Mountains running westward of Peel's River, the opposite banks rising precipitously several hundred feet until they joined the mountains beyond. Having no time-piece with me, I cannot speak positively as to time, but it would have been probably between 10 and 11 p.m., with a fresh breeze blowing from N.E. and very cold. The phenomenon was evidently very near the earth, for it appeared between me and the trees on the opposite bank of the river, which could not have been

forty feet above the level of the stream, the trees toward the top of the hill being high above it. Large compact masses were moving from E. to W. and bright streamers passing in the same direction in quick and vivid flashes, then returning to the zenith would from thence spread out to the N. and S. in beautiful waves or clouds, and sheets of light of the most beautiful colors until they disappeared and left the sky entirely clear. Every time the streamers passed from E. to W. they were accompanied by a hustling noise, such as would proceed from the gentle waving of a silk flag. But in returning from the W. to E. I am not conscious of having heard any sound proceed from them."

BOOKS ADDED TO THE R. A. S. C. LIBRARY

MOST OF THEM RECENTLY

"Aristarchos of Samos," by Sir Thomas Heath.
"Meteorology," by Willis Isbister Milham.
"Astronomy," by Harold Jacoby.
"The Foundations of Science," by Henri Poincaré.
"Popular Lectures and Addresses," by Lord Kelvin.
"Stellar Motions," by W. W. Campbell.
"Are the Planets Inhabited?" by E. W. Maunder.
"Ways of the Planets," by Martha Evans Martin.
"Milton's Astronomy," by Thomas N. Orchard.
"Scientific Papers of Sir William Herschel," Two Volumes.
"Book of Sun-Dials," by Mrs. A. Gatty.
"Le Système du Monde," by Pierre Duhem. Vols. I., II.
"Stellar Movements and the Structure of the Universe," by A. S. Eddington.
"Principles and Methods of Geometrical Optics," by J. P. C. Southall.
"Essai de Cosmogonie," by E. Belot.
"American Ephemeris and Nautical Almanac" for 1916 and 1917.
"History and Discription of the Royal Observatory, Cape of Good Hope," by Sir David Gill.
"Report of Chief Astronomer for 1910, Ottawa."

ECHOES FROM EXAMINATIONS

These spots [sun-spots] are scattered over the surface of the sun but their preference seems to lie nearer the lake region.

We may use one of the craters as a station in observing the rotation of the sun. It will make a distinct object and may easily be picked out.

. . . . . .

This star [Algol] appears quite bright when quite quickly it becomes dim. This is caused by the followers of Algol, which are black bodies, passing in front of it.

. . . . . .

A sidereal day is the interval between two successful transits of the vernal equinox.

C. A. C.